LEAN THINKING AND THE FACTORS NECESSARY FOR ITS SUCCESS

By

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Stand on the production floor all day and watch–
you will eventually discover what has to be done.
I cannot emphasise this too much.
(Ohno, 1988, p. 78)

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[AND] NOW TO **THE KING OF THE AGES**, INCORRUPTIBLE, INVISIBLE, THE ONLY GOD, BE HONOUR AND GLORY FOR EVER AND EVER. AMEN (1 TIMOTHY 1:17). BECAUSE OUT FROM HIM AND THROUGH HIM AND TO HIM ARE ALL THINGS. TO HIM BE THE GLORY FOREVER. AMEN (ROMANS 11:36).[1]

[1] http://online.recoveryversion.org

Abstract

Lean management is becoming the standard for systematic productivity improvement, but the majority of implementations fail to sustain. Hence, the critical success factors for lean were the focus of this work. Literature review showed that the causality for lean success was not empirically developed beyond case study contextualisation. A multifaceted work was developed with contextualisation studies, survey of lean knowledge (758 responses), and a comprehensive case-study questionnaire (1253 responses from 44 countries). The statistical methods included exploratory factor analysis and path analysis by structural equation modelling (SEM). The first questionnaire revealed two different understandings of lean, and the second explored the underlying causality for lean success, including contingency for business size and product variety.

Many contributions to the body of knowledge issued from this work. First of all, there was a methodological contribution, pioneering explorative structural modelling of full scope lean implementation. Second, SEMs of the *lean knowledge-based view* showed the profound positive effects of management knowledge on the primary factors for lean success. These factors were shown to be leadership and employee development. Third, the most beneficial lean methods were highlighted for specific scenarios. Fourth, the negligible and negative effects of a consultant-based approach to lean were uncovered. The results showed that the majority of consultants did not aid the long-term performance and sustainability of lean but significantly hindered it, except where *masterful* consultants acted as coaches. Fifth, a shortage of lean knowledge was observed in New Zealand; their participants averaged only half of what the USA's did. Sixth, as culture has been emphasised in current literature, the present danger of overly focusing on it was discussed. Seventh was a conceptual contribution integrating lean and risk management, and a practical application with a risk analysis. This developed a risk matrix for the assessment and prioritisation of implementation components. Eighth, some adjustments to government lean strategies were proposed. And finally, the work integrated the findings in a tangible stage process model for implementation in SMEs.

The dissemination of this knowledge has the potential to enhance productivity and commercial success of industries in New Zealand and abroad through successful lean implementations. Lean is not a weak methodology but it has been misunderstood and misapplied.

Authorship

This submission is the original work of the author to the best of his knowledge and belief, it contains no material previously published or written by another person except where explicitly defined.

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This work was conducted 90% by the candidate. In supervisory sessions with Dr. Dirk Pons normal suggestion and direction were provided. The case study was carried out, and the work was drafted 100% by the candidate. The candidate prepared and presented the work at a conference. Later Dr. Pons helped the candidate to condense the work for journal publication. The majority (~90%) of the lean-risk work in the thesis came from the original conference presentation.

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Name: Dr. Dirk Pons Signature: Date: *3 Feb 2014*

Dirk Pons

Abbreviations

5 Whys	Simple root cause analysis (ask why 5 times)
5S	Lean method
AM	Agile Manufacturing
ANOVA	Analysis of Variance
APA	American Psychological Association
AS	Agile Software
C&RT	Classification and Regression Tree
CHAID	Chi-Square Automatic Interaction Detection
CI	Continuous Improvement
Comm	Communication
Cont	Continued
CSF	Critical Success Factor
Devel	Developed
DMAIC	Define Measure Analyse Improve Control
EFA	Exploratory Factor Analysis
Elimin	Elimination
Eng	Engineering
ERP	Enterprise Resource Planning
Impl	Implementation
IMVP	International Motor Vehicle Program
Incr	Increase
JIT	Just in Time
KPI	Key Performance Indicator
LEI	Lean Enterprise Institute
LERC	Lean Enterprise Research Centre
LHS	Left Hand Side
L-LSS	Lean and Lean Six Sigma
LSS	Lean Six Sigma
Mngmnt/Mgmt	Management
MRP	Material Resource Planning
NZ	New Zealand
NZTE	New Zealand Trade and Enterprise
Obs	Observations
OECD	Organisation for Economic Cooperation and Development
OEE	Overall Equipment Effectiveness
OM	Operations Management
Org	Organisation for Economic Cooperation and Development
PAF	Principal Axis Factoring
PCA	Principal Components Analysis
PDCA	Plan Do Check Act
PDSA	Plan Do Study Act
Philos	Philosophy
PLS	Partial Least Squares
QC	Quality Control
Qual	Quality

RHS	Right Hand Side
SEM	Structural Equation Modelling
SME	Small and Medium Enterprise
SMED	Single Minute Exchange of Dies
Sys	System
TOC	Theory of Constraints
TPM	Total Productive Maintenance
TPS	Toyota Production System
TPS	Toyota Production System
TQC	Total Quality Control
TQM	Total Quality Management
TWI	Training Within Industry
Vis	Vision
VRIN	Valuable, Rare, Inimitable, And Non-substitutable
VSM	Value Stream Mapping
WIP	Work in Process

1. Background

Lean, a strategy developed for production improvement in the mass production setting, is now considered a way of thinking that can be applied to change business practice universally (J. P. Womack & Jones, 2003). Because of this lean thinking has been called "lean management" (Emiliani, 2006). The Toyota Production System (TPS), from which the lean concept developed, has been described as "a system for the absolute elimination of waste." When wasteful action is gone less effort, space, and capital is required; lead time is reduced; and quality increases whilst the cost of quality decreases. Along with the elimination of waste, the *respect for humans* is considered an equally important principle for lean management. This is confirmed by many works (Ohno, 1988; Shingo, 1989; J. P. Womack & Jones, 2003; Schmidt, 2011; Hines, Found, Griffiths, & Harrison, 2008; LEI, 2011).

This document details a research into lean thinking and the factors necessary for its success. Whilst initiated in New Zealand manufacturing and service organisations, the research and its cases went well beyond that local context. It was recognised that the typical size of a New Zealand manufacturing business corresponds to the global definition of a small to medium enterprise (SME). Thus the discussions addressed the challenges of SMEs in detail yet was not limited to New Zealand or the SME but firstly conducted a broader analysis of lean success and then narrowed back to specific contexts, especially business size and product mix.

1.1 Motivation

Besides the needs of local industry, this study was motivated by the author's personal experience. Antony, originally employed as a designer of automated machinery, redirected his career in 2008, taking a manufacturing management role in a SME. The company had advanced manual and computer controlled machinery along with design and precision assembly capability. Additionally, the managing director had sourced dedicated and highly capable trade and administrative staff and formed a solid advisory board. Besides these positive internal aspects, there was also a good client base and workload. However, the company struggled with profitability, as a reflection of poor productivity.

The business was introduced to lean manufacturing as a means to address productivity. This introduction came through networking with other businesses and the promotion of lean by New Zealand Trade and Enterprises (NZTE), a government agency. The business saw lean as a way to maintain competitiveness in a global market by reducing waste, increasing quality, and reducing lead times without increasing cost. The company began a lean implementation by sending five key staff members to an NZTE introductory course. Along with this, all employees were trained with a video series.[2] But good intentions aside, after two years lean behaviours had not been embedded in the organisation, nor were its benefits apparent. Although the

[2] A series of videos by the Society of Manufacturing Engineers

leadership believed there was benefit to lean, it was clear that the important factors for lean implementation were not readily understood. This experience, and the desire to understand what really drives productivity and the success of a lean business became the motivation for this research.

In addition to the above personal experience there was the local motivation. In New Zealand there is a great potential to increase the nations profitability through enhanced productivity. Lean has become a leader in manufacturing and enterprise improvement strategies; it is now considered an essential part of a manufacturing endeavour (Selko, 2012). Because of this recognised fact and the untapped potential in New Zealand, New Zealand Trade and Enterprise (NZTE) started the Aichi Lean manufacturing initiative in 2004 (M. Wilson, Heyl, & Smallman, 2008). The program mainly focused on the manufacturing sector, but in 2011 was supporting the "leaning" of service organisations (Gardiner, 2011; Goodyer, Murti, Grigg, & Shekar, 2011). The manufacturing sector in New Zealand was an obvious initial target for improvement, and a reason for promoting lean manufacturing. The manufacturing industry is New Zealand's fourth greatest generator of gross domestic product at around 12% and is its third largest employer at 11.5%, see Figure 1[3] (Statistics NZ, 2011).[4] Although lean showed promise, the businesses that participated in the programme had limited success in implementing it. The lean activities did not fail in delivering improvement but in many cases did fail in delivering sustained and continuous improvement. This was confirmed by multiple case studies (MED, 2010; Goodyer, Murrti, Grigg, & Shekar, 2011; Murti, 2009). Therefore the need to improve productivity in New Zealand could be addressed by understanding the factors for lean success.

When considering the New Zealand manufacturing industry, it is difficult to neglect the many SMEs that make up the large proportion of businesses in this industry. This is well described by Goodyer et al. (2011):

> *"Like most of NZ industry, the manufacturing sector is largely composed of very small enterprises. NZ has no formal legal definition of an SME. The MED uses the criterion of up to 19 employees as typifying an NZ SME (MED, 2011). The NZ Centre for SME research (NZ SME, 2011), alternatively, suggests that SMEs make up 99% of all NZ businesses and account for about 60% employment and specify that the SME sector broadly covers micro-enterprises (fewer than 5 staff), small enterprises (6-49) and medium enterprises (50-100). Organisations with 100 plus staff are classified as large enterprises. On an international platform even many of the 'large' NZ companies would be considered SME's. Therefore on a global scale this study is contributing to research on sustaining lean transformations in SMEs."*

Therefore, the SME component of this work, as complementary to the work of Goodyer et al. (2011)[5] contributes to the majority of New Zealand industry whilst also the success of lean in SMEs worldwide.

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[3] A pie chart for GDP by industry was not included here because of the ambiguities in the industry groupings. However, such a chart would put manufacturing in similar proportion and position as the one shown for jobs filled.

[4] Various relvant tables from Statistics New Zealand are reproduced in the appendix (p. 704).

[5] See also Stamm (2011) for similar lean research focusing on SMEs and the particular characteristics of New Zealand.

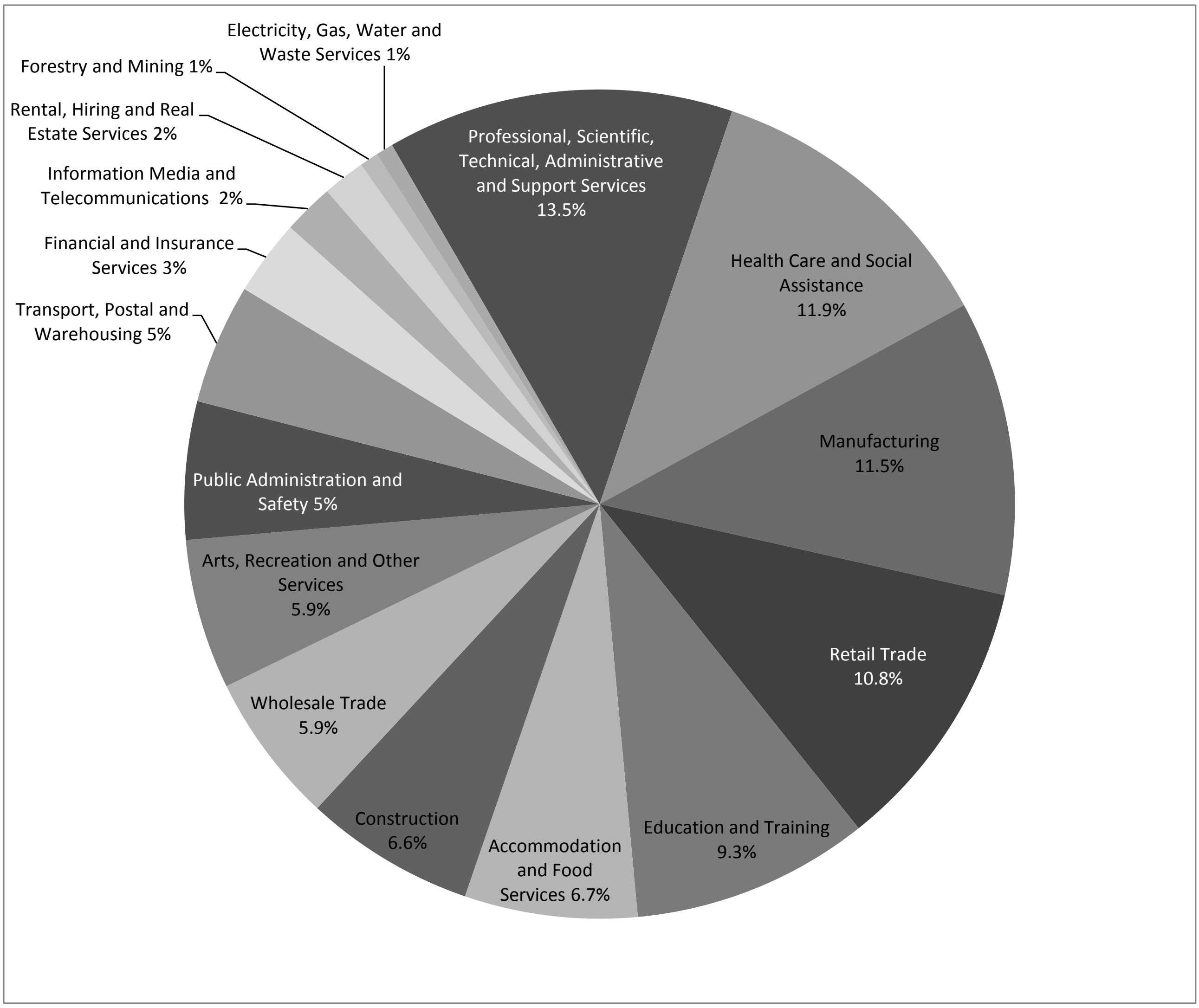

Figure 1 Filled jobs in New Zealand by industry sector for Quarter two 2011. Pie chart showing the manufacturing sector as the third largest employer. The manufacturing sector at 11.5% was only 2% behind the leading employer *Professional, Scientific, Administrative and Support Services* at 13.5%.[6] (Image: A. Pearce)

1.2 Problems with the Current State of Art

The problems with lean success are identified primarily in the emphasis of its tools and processes rather than the required strategic level of thinking. The Lean Iceberg model is used to explain this (Hines et al., 2008). This model describes that lean technology, tools, techniques and processes can be seen on the surface; they are easily grasped and visible when visiting a lean enterprise. These above the waterline, visible aspects are relatively easy to implement and do deliver improvement but are not sufficient for sustainability. Sustainability is achieved by including the invisible or below the surface items of the Lean Iceberg. The below the surface aspects are 1. strategy and alignment, 2. leadership, and 3. behaviour and engagement. These are the *respect for humans* aspects that sustain and eventually drive a lean enterprise. These aspects

[6] The data for this chart was sourced from Statistics New Zealand (Statistics NZ, 2011).

are typically missed in lean implementations. These implementations deliver initial wins but not the strategic and cultural changes necessary for sustainability. This has been seen both globally and locally in New Zealand (Hines et al., 2008; J. P. Womack, 2007; Schmidt, 2011; Found et al., 2006; Goodyer et al., 2011).

There is knowledge regarding the benefits of lean and at least to some extent how to have a successful lean implementation. Previous research has correlated exposure to lean information with management commitment and in turn management commitment is linked to successful implementation (T. A. Boyle, Scherrer-Rathje, & Stuart, 2011). However the many failed instances of lean indicate that if the knowledge does in fact exist, it is being underutilised.

An initial analysis of lean in New Zealand was undertaken by interview (Gardiner, 2011; Joiner, 2011; Reaney, 2011). In these interviews it was reported that there was not only a level of ignorance of new knowledge but also a lethargy or lack of interest in seeking out the new knowledge. It appeared that, in New Zealand specifically, there is a barrier to the implementation and success of lean due to the lack of knowledge or ignorance in firms that could otherwise benefit from lean. In addition to this are the inherent limitations of the SME.

The literature review also showed that the research into lean success is largely contextual, and would benefit from further delineation through quantitative empirical analyses.

1.3 Purpose Statement

The purpose of this work was to identify and explore lean success factors including the extent to which knowledge, specifically the business leaderships' own knowledge, is a factor of the success or failure of a lean implementation.

This was a worthwhile exercise because of the potential to enhance productivity and the commercial success of those industries both within and beyond New Zealand.

1.4 Structure

The thesis structure follows a typical research approach. First, the literature review discusses three intersecting bodies of knowledge—lean management, organisational development (change management), and risk management. Second, the methodology is given. Third, a contextualisation study is presented. This consists of interviews and case studies which grounded the work in reality. Fourth, the main quantitative analysis follows, covering one general knowledge survey (758 responses) and one case-study questionnaire (1253 responses from 44 countries). From the analysis, the final sections discuss the findings and give implications, including practitioner models for lean implementation. Although this work incorporated an early contextualisation study, the philosophy was significantly positivist, relying on the scalar questionnaire data and quantitative analysis, for example structural equation modelling.

2. Literature Review

The research developed a *lenses* approach to review. Each lens was a looking glass, giving a different perspective and understanding of lean implementation success. The primary lens was *lean itself including the principles, method, and tools.* To this, two additional angles or lenses were added to give perspective and understanding of lean implementation success. These additional lenses were *organisational development* for transformational change, and *risk management* for decision analysis. These lenses are represented by three overlapping triangles in Figure 2. Literature from the primary lens, lean itself, is merged where appropriate with the others.

This work recognised lean implementation as an organisational development and transformational change needing sustainability. The lens of organisational development was used to investigate lean in this way. This is developed under Organisational Change for Lean Implementation, page 37.

The third lens was Risk Management, page 66. Lean implementation involves many decisions that may positively or negatively affect an implementation. The decisions of a lean implementation, e.g. what tools to introduce, have various consequences. The perspective of risk management provides principles and tools to minimise threats of failure and maximise opportunities of success.

Figure 2 The three *lenses* for this study of lean implementation success were lean, organisational development, and risk management. (Image: A. Pearce)

2.1 Lean

A very basic definition of lean is doing more with less[7], hence being lean. Lean in this work takes its definition particularly as developed in the text *Lean Thinking* (J. P. Womack & Jones, 1996) and built specifically on by the lean sustainability literature, e.g. Hines et al. (2008, 2011).

Lean is a strategy developed for production improvement. Originating in the mass production setting of the automobile industry, lean is now said to be applicable to business practice universally (J. P. Womack & Jones, 2003) and has been called *lean management* (Emiliani, 2006). The Toyota Production System (TPS), from which the lean concept developed, has been described as "a system for the absolute elimination of waste" (Shingo, 1989, p. 67; Ohno, 1988). When wasteful action is gone, less effort, space and capital is required; lead time is reduced; whilst quality increases and the cost of quality decreases (LEI, 2011). Lean functions to drive an organisation towards perfection, facilitating continuous improvement of business processes by removing waste or wasteful action. It involves considering the purpose of the organisation and how it provides *value* to the customer. The process by which that value is created is analysed for the removal of waste. Waste is identified by looking at the whole system and its product flow, rather than seeking a localised improvement. Focusing on the people of an organisation, lean creates a culture that empowers staff at all levels to make innovative changes that improve productivity by reducing wasteful action, muda.[8]

A lean system, like the TPS, is considered as one that focuses on the elimination of waste but also possesses the equally important "*respect for humans"* principle (Emiliani, 2006; Ohno, 1988). These principles work synergistically in an ideal lean model. In the lean business model, effort is invested in constant improvement meaning that defects occur less frequently or do not reoccur and the system moves towards a state of perfection. This type of system is one of continuous improvement and is a stark contrast to an arrangement where managers and workers exert much effort fire-fighting, expediting, and fixing causes of defect (Delbridge, 1998, p. 180) only at the surface rather than at the root cause (Ohno, 1988).

Lean can be considered a culture rather than a mere method or set of tools and techniques (Kanban, 5S, TPM, SMED and others)[9] (Hallam, Muesel, & Flannery, 2010; J. P. Womack, 2007). With this view, lean is not a tool or a program in itself but a manufacturing strategy turned enterprise strategy which prescribes a journey of continuous improvement for the process, workshop or organisation to which it is applied (J. P. Womack & Jones, 2003; LEI, 2011; Emiliani, 2006; Schonberger, 2007).

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[7] Lean is not about reducing staff levels, as it is sometimes misconstrued, but rather recommends maintaining and redeploying staff. Some lean examples show employers guaranteeing employment to reduce backlash from employees at the beginning of a lean implementation. This is also used to encourage worker flexibility. (J. P. Womack & Jones, 2003; Ohno, 1988; Joiner, 2011)

[8] Because the roots of lean are in Japanese manufacturing the Japanese words are often used to give strong reference to key lean tools or concepts. Many times these words give more meaning than their simple English equivalent. Here *muda*, the Japanese word for waste, is referred to. It however implies more than just waste but wasteful action.

[9] This thought and the problem of considering lean as a set of tools only is discussed in more detail throughout this work.

2.1.1 Waste and Value

An organisation, whether service or product oriented, has processes and those processes consist of activities. These activities from a customer's perspective either add value or do not add value to the product or service (Shingo, 1989, p. 76; J. P. Womack & Jones, 2003). Take an imaginary product, a widget for illustration. To produce a widget requires activity, typically plant and machinery is also required, but for this simplified illustration consider all as activity. In a real process some of that activity would be value adding and others are non-value adding. If a widget is processed with a treatment not required by the customer then that would be waste or if it is transported large distances from point A to point B without increasing its value to the customer that is also waste. This wasteful activity is what is referred to as non-value adding activity. Typically activity that adds value by transforming the product is considered value-adding activity. The following three figures illustrate how a typical organisation increases production as compared to a lean organisation. Figure 3 depicts an organisation's activities to produce widgets. These consist of a percentage of value adding and non-value adding activity indicated by the box (cell size). The organisation in Figure 3 produces widgets with activity of two thirds non-value adding activity and one third value adding activity as indicated by box size.

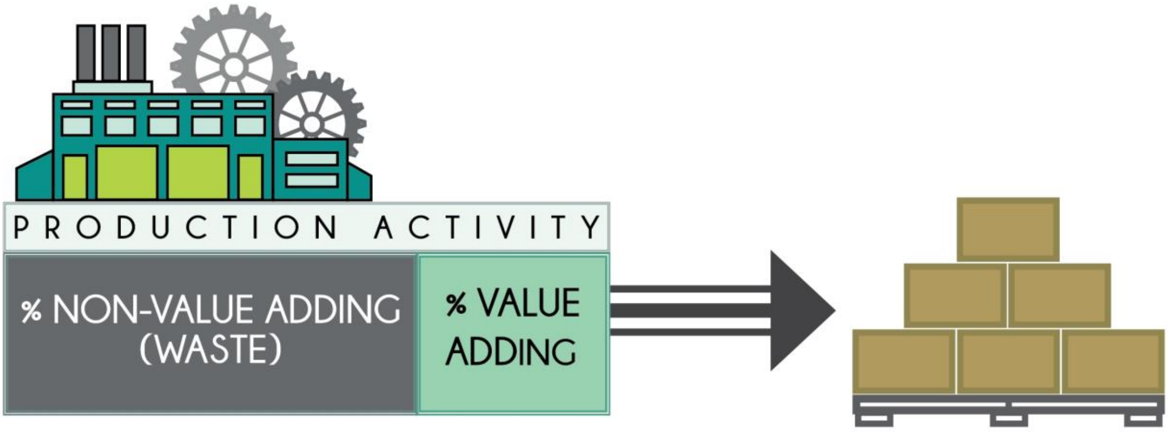

Figure 3 Illustration of an organisations activity to produce widgets.
(Image: A. Pearce)

Figure 4 (below) illustrates how a typical organisation increases productivity. All of the organisations activities are increased in order to produce twice the desired quantity of widgets. This may involve additional staff working extra shifts but carrying out the same activities. Both wasteful (non-value adding) and value adding activity is added.

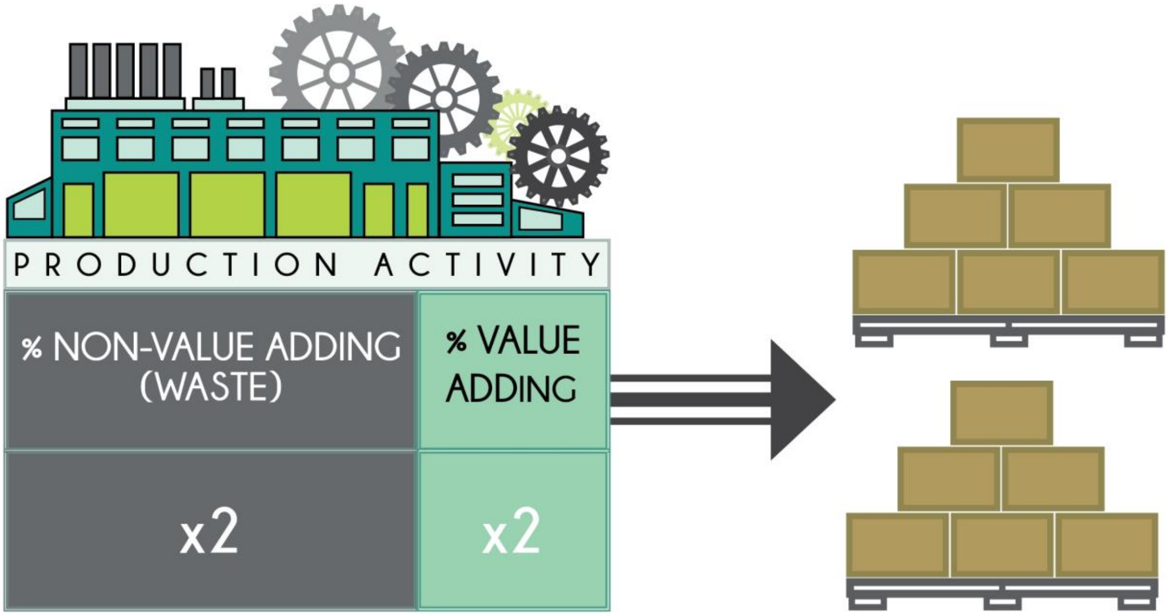

Figure 4 In a typical organisation, value adding and non-value adding activity is increased to increase output. (Image: A. Pearce)

Figure 5 shows how an ideal lean organisation increases production of widgets by elimination of waste. Their method aims to increase only value adding activity, decreasing non-value added activity; decreasing waste.

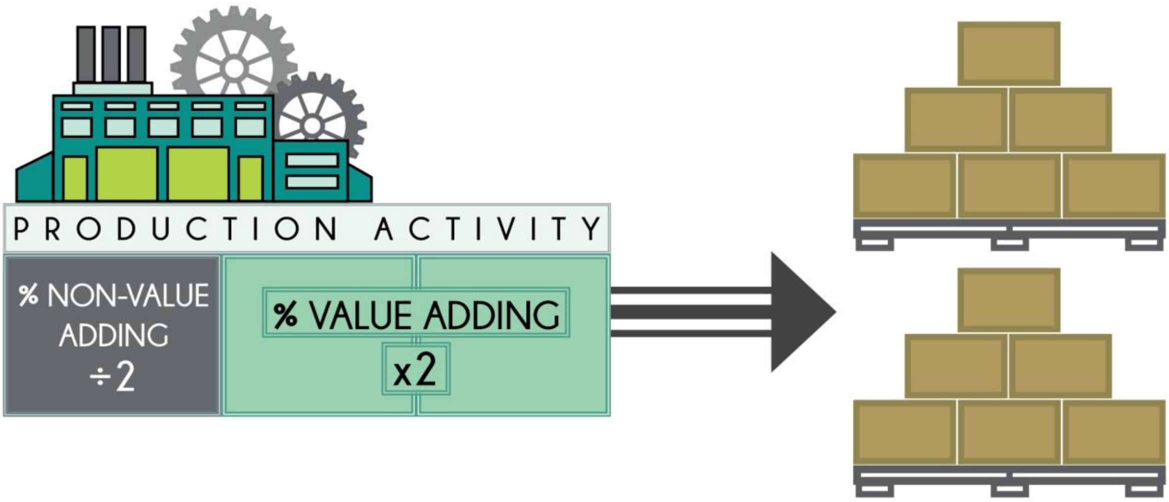

Figure 5 In a lean organisation, non-value adding activity is decreased leaving more capacity for value adding activity. (Image: A. Pearce)

A lean organisation is one in which waste, or non-value adding activity, is significantly removed. Some non-value adding activity is completely unnecessary and can be removed instantly; however others are deemed as necessary, at least for the time being, and remain until they can be removed. Often the 7 wastes prescribed in the text Toyota Production System (Ohno, 1988, pp. 19, 20) are given as a guide to aid in identifying value and non-value adding activity; these are:

1. Overproduction
2. Waiting
3. Unnecessary Transportation
4. Unnecessary Processing
5. Inventory
6. Defects in products

This list is generally preserved in this form however some choose to add to or adjust it. Womack and Jones (2003) add a point seven: the design of goods and services that do not meet people's needs. Some debate over which points to include and whether or not this was Taiichi Ohno's definitive list (Miller, 2006). However what is essential to understand is that waste exists and needs to be identified and eliminated in a journey towards perfection.

Besides muda, mura, and muri are important concepts in waste (Hines et al., 2008; Liker, 2004). Mura represents waste due to unevenness. This is seen in highly fluctuating demand and can be limited through level scheduling, hence a focus on level selling and limiting expediting. Muri is the waste of overburdening people and equipment. This is specifically relevant to the respect for peoples principles. Ultimately mura brings in muri and can undermine previous efforts to eliminate muda.

2.1.2 Five Key Principles

Lean Thinking (J. P. Womack & Jones, 1996) emphasises that removing waste from a system by the following steps:

1. Define value
2. Map the value stream
3. Develop flow
4. And Implement pull

These four steps become a cycle to perfection, the fifth principle, which is linked to the Plan, Do, Check, Act (PDCA) cycle (Deming, 1986, p. 88). The PDCA cycle in principle is integral to lean and other quality and continuous improvement systems (Hines et al., 2008; Liker, 2004, p. 246). The lean variation of the PDCA, as shown in Figure 6, forms the five principles of lean as identified by Womack and Jones (J. P. Womack & Jones, 1996, 2003; Hines et al., 2008).

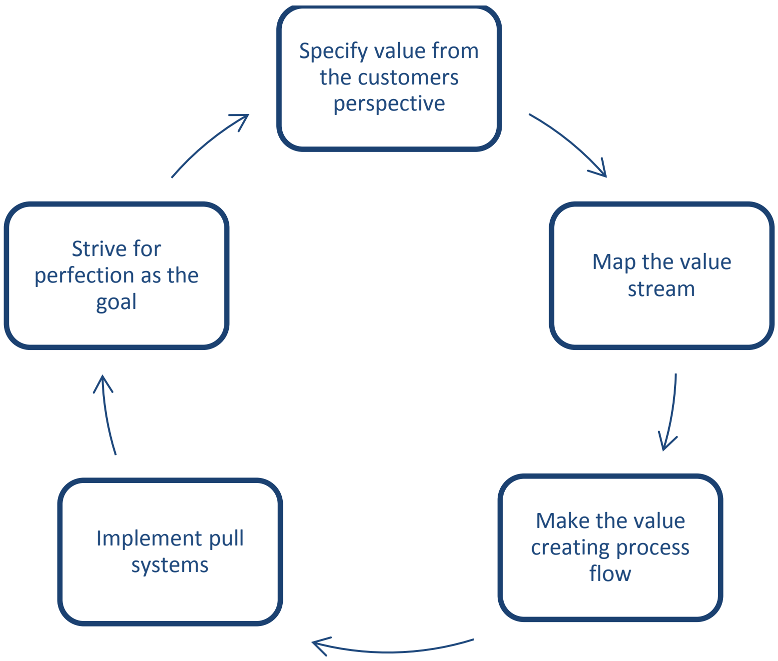

Figure 6 The five lean principles: specify value, map the value stream, make the value creating process flow, do this from the pull of the customer, and strive for perfection (J. P. Womack & Jones, 1996). This cycle is linked to Deming's PDCA cycle.

In order to truly understand what is wasteful in a system, lean thinking prescribes it as key to first understand what adds value[10] to the customer. Starting with a product or service, define what is valuable to the customer. Then, identify and map the value stream. Various types of process maps can be used for this (Hines et al., 2008). This step is used to prescribe the journey towards, or what needs to be done to reach, perfection. As a tool it points to what should be improved on next for that product or service process. It might indicate the need to completely restructure a set of processes or the improving of one particular operation. Value stream mapping (VSM) is accomplished by mapping the processes for transforming a product or providing a service, and is used to identify the waste in the steps of the process. Practitioners are encouraged to map the current state and then the ideal future state, the goal for perfection of that process (J. P. Womack & Jones, 2003; Rother & Shook, 2003; Hines et al., 2008).

Developing flow is the third prescribed step for forming a lean system. Single-piece flow, as seen with an ideal *just in time* (JIT) manufacture system, possesses no-waste in the form of inventory and overproduction, this is ideal for a lean system. Lean thinking prescribes that where at all practicable process steps should be

[10] A critical point in the lean thinking is the focus on value. Often however, value creation is seen as equal to cost reduction. This represents a common yet critical shortcoming of the understanding of lean. Value can be increased by either creating value for the customer or eliminating waste in the production of that value e.g. the particular item a customer desires. (Hines, Holweg, & Rich, 2004)

lined up one after the other to produce flow from operation to operation, process to process. Once flow is achieved pull can be implemented. Pull is that mechanism of initiating production in a lean system. Pull in essence links the process of a product or service to the customer directly and is a mechanism by which just in time (JIT) flow is achieved. Ideal lean production is initiated when and only when the customer calls for it, pulling value from the system in the form of a product or service. In this way overproduction is eliminated. If this process is perfected when the customer demands or pulls value, in the form of a product or service, it flows to them at the rate they require it.

Value Creation vs. Cost Reduction

The discussion of value versus waste has become important in considering the strategic perspective of lean, that is in terms of value creation (Hines, Holweg, & Rich, 2004). It is significant that the five principles in Lean Thinking (J. P. Womack & Jones, 1996) began with defining value in the eyes of the customer. The proper understanding of waste is inseparable from the understanding of value. If waste elimination is disconnected from creating value to the customer, so called improvements provide cost reduction but may lose the inherent value to the customer.

2.1.3 Principle Components

Lean has various tools or methods that were derived from the TPS and others that are a further development. These tools are not the focus of this work however some of the key elements are worthy of discussion here. Womack and Jones themselves (J. P. Womack & Jones, 2003) do not cover a multiplicity of tools but rather the principles of the system from which persons can learn and be guided to implement in their own setting.

Just in time manufacturing is sometimes mentioned near synonymously with lean e.g. “JIT/Lean” systems (Schonberger, 2007). However lean, and the TPS, are considered to have two *pillars* that hold up the lean house. JIT and *autonomation* are these two pillars. These pillars reflect *eliminating waste* and having *respect for humans* (Ohno, 1988; Emiliani, 2006). The pillars stand on a base of stability with heijunka (level scheduling), standard work, and kaizen (continuous improvement). With a customer focus, the pillars uphold a system to achieve highest quality, lowest cost and shortest lead time.

The first of these pillars, the JIT principle, is clearly seen in product assembly when the components for a certain process only arrive as needed, i.e. just in time for manufacturing. This implies one piece flow and is against conventional methods. Traditional manufacturing and accounting practice often limit lean progression (Cunningham & Fiume, 2003). Economies of scale, though seemingly logical is a major concept to overcome[11] and is entrenched in the psyche of experienced management and factory workers. For example, in economies of scale a large lot or batch size is thought to lower cost by reducing the number of

[11] With economies of scale and the associated concept that a large batch is “better” also comes the concept of large dedicated machinery. One concept of the lean thinking in lining up processes for flow is “right sized” machinery should be used(J. P. Womack & Jones, 2003), e.g. a small saw capable of making the cut for a particular operation in a particular product line rather than batching parts in front of a large semi-automated saw capable of processing all product cuts.

setups but this actually increases inventory and delivery time (Goldratt & Cox, 2004). Lean thinking sees large batches as only reducing costs locally (creating a local optimum); they devastate flow and efficiency of the system as a whole. Alternatively batch size should be reduced and a way to minimise setup time implemented. Otherwise inventory waste soon builds up at each step of the production process. In terms of stagnant cash flow, it is easy to see that inventory sitting is waste. However this inventory also represents overproduction of that product. Batching and holding inventory in turn produces other waste in transportation, storage, undetected defects, damaged and stored obsolete parts. Lead time also extends as batch sizes increase, this is extremely unfavourable to customers. Refer to the seminal works (Ohno, 1988; J. P. Womack & Jones, 1996)**.**

Middle managers may not quickly understand this JIT thinking and the changes taking place; unfortunately this may result in the loss of these staff members (J. P. Womack & Jones, 2003; Joiner, 2011). The change is challenging. To properly implement such changes, and perform a lean transformation typically takes a change agent. This person needs the right vision, knowledge and courage to change from the status quo, the embedded ways of an organisation. This also needs the right level of authority and support from management (Ohno, 1988, pp. 31, 36). This is typical of successful recorded lean cases; as seen in Toyota's transformation, American implementations, and New Zealand's own cases (Ohno, 1988; J. P. Womack & Jones, 2003; Joiner, 2011).

The second pillar, autonomation, builds intelligence into a process; working to find faults it drives continuous improvement. Lean systems can be thought of as fragile, not having buffers of safety stock (Krafcik, 1988; J. P. Womack, Jones, & Roos, 1990, p. 103). The lack of buffers and safety stock in these systems show up defects as they occur; they force a solution to be found before production continues (Ohno, 1988). This is the essence of autonomation (Jidoka) and flows onto tools for mistake proofing (poka-yoke). And necessitates the use of tools such as the *5 Whys*, i.e. asking why 5 times, in order to find the root cause of defects. The employees are empowered to solve the problems and make the necessary changes. This respect for humans with autonomation means lean systems allow and even should force change for continuous improvement.

Level scheduling (Heijunka) is an important component in addition to the pillars. It is used to support the fragile JIT system. Level scheduling smooths out fluctuating demand in order to maintain flow in a system. Techniques such as level selling and deciding in which order to process products helps with providing a level schedule for a JIT production system. It is difficult to get a JIT system up and running, but once mastered it is an extremely efficient, effective and flexible way of manufacturing (Ohno, 1988; Shingo, 1989; J. P. Womack & Jones, 2003).

Though some principal components are discussed above, the focus of this work is not on the tools but rather lean success in achieving waste elimination for the flow of value to the customer. Other lean tools like *Kanban*, *Takt Time,* and *5S* are discussed in context of the historical development of lean and other places in this work where it is seen beneficial.

2.2 History and Development of Lean Management

To further answer the question "What is lean?" or "What is lean thinking or lean management?" it is helpful to consider its beginnings and development. That is the focus of this first section.[12]

Developed overtime, lean eventually appeared in the form of concepts and tools for the practice of lean manufacturing; i.e. lean production. As it progressed, lean became definable as an enterprise thinking (J. P. Womack & Jones, 2003).

Lean's development has some clear landmarks in history although its beginning is not so clearly defined. As discussed earlier, lean prescribes a journey towards perfection through eliminating waste or wasteful action. It has some key principles and accompanying tools as seen in the Toyota Production System. Additional methods have also been added; such as six sigma. Although not specifically a TPS or lean tool six sigma has formed a hybrid with lean in practice, *lean six sigma*. One of the common stated examples of lean thinking in history is the Arsenal of Venice (J. Womack, 2004; Lean CEO, 2011).

> *"…the Arsenal in Venice [was] established in 1104 to build war ships for the Venetian Navy. Over time the Venetians adopted a standardized design for the hundreds of galleys built each year to campaign in the Mediterranean and also pioneered the use of interchangeable parts. This made it possible to assemble galleys along a narrow channel running through the Arsenal. The hull was completed first and then "flowed" past the assembly point for each item needed to complete the ship. By 1574 the Arsenal's practices were so advanced that King Henry III of France was invited to watch the construction of a complete galley in continuous flow, going from start to finish in less than an hour. …the idea of continuous flow - which many in our community probably think was invented by Henry Ford - was being practiced more than 400 years ago, but then largely forgotten!" (J. Womack, 2004).*

The author believes lean's conception could be traced near to the origins of man, at least in a philosophical sense,[13] although there is no intention to enter that as a debate. However, there are more defined cases of lean

[12] The work here is not to neglect the writings of others like that of Matthias Holweg who recorded "The genealogy of lean production" (Holweg, 2007) from the perspective of the history of the Toyota Production System (TPS) with its introduction acceptance and decoding in the western world. The author's desire here is to develop a full understanding of lean by seeing its history in detail and to contribute further to this body of knowledge. In later sections an investigation into New Zealand's own lean journey is presented. Holweg (2007) also pointed to additional documentation of the development of automotive production system (Hounshell, 1985; R. Boyer, Charron, Jürgens, & Tolliday, 1999) and the story of the Toyota Production System (Cusumano, 1985; Fujimoto, 1999; Ohno, 1988).

[13] This statement is pointing to lean practices as the product and application of human innovation and ingenuity. The existence of this ingenuity of human beings with its product and application naturally would coincide with the existence of human beings. An example of this ingenuity is discussed later with the case of Fisher and Paykel in New Zealand. As Taiichi Ohno had in Japan Fisher & Paykel in New Zealand began practicing lean principles of flexible manufacturing and quick changeovers, not because they learnt about lean or its principles, but as a product of their own ingenuity and circumstance.

thinking and the main references of the 20th century are included here.[14] These historical examples are included not merely for interest sake but because of their benefit in unravelling an understanding of lean thinking.

This history of lean gives a kind of longitudinal study that identifies the key elements of lean thinking and why they are considered necessary. In one sense, the past is not worth dwelling on, but looking at the history of lean shows how the key elements were developed to their current state. This can help plot the road map for the future, i.e. how lean thinking can be advanced further. It also gives a window into the minds of true innovators that went before and the type of logic and thinking they possessed, in this case the thinking that became lean.

2.2.1 Henry Ford, Standardisation and Flow for Mass Production

When considering the development of the automobile industry, which is closely aligned with the development of lean manufacturing, it is hard to go past the achievements of Henry Ford in the early 1900's. Ford's major achievement is seen with the mass production of the Model-T[15] (Ohno, 1988; J. P. Womack, 2002; J. Womack, 2004; Lean CEO, 2011). Flow, one of the key requirements of a lean system (J. P. Womack & Jones, 2003), was achieved by lining up processes for manufacturing one after the other in a moving assembly line. The hidden achievement was that this system of manufacture had been made possible by using standardised parts[16] in a product that had been designed for manufacture. Workers on a moving assembly line completed repetitive tasks that required little skill[17] for the processing of standard parts. Their work was checked with gauges to ensure components did not require modification at final assembly. Ford developed purpose-built machinery for handling single parts as opposed to using tools capable of manufacturing multiple components but requiring much skill and set up time (J. P. Womack et al., 1990; Krafcik, 1988). With time, Ford also became vertically integrated to an extreme. Raw material that came in one end of the Ford factory was processed in their own glass factory and steel mill. Rubber came from the Ford plantation in Brazil. Iron ore and coal arrived by Ford ships and there was also Ford's rail.

In 1914, Ford's continuous-flow production system was fully setup in Highland Park. The chassis assembly time went from 12 hours to under three by use of continuous flow. The achievement of Ford revolutionised the automobile industry and began to be applied by other manufacturers also (J. P. Womack et al., 1990; J. Womack, 2004). Although Ford did not approve of war, he eventually helped the effort of World War II with a now famous bomber plant, Willow Run. The result was that in 1943 the manufacturing time on the B-24

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[14] The website of Lean CEO (2011) has a timeline that is stated to be further developing with more cases of lean practice. Holweg (2007) includes an informative time line that also points to the key documentation of lean's development.

[15] Ohno (1988) also praised Ford's consideration of waste, standardisation and his view for the future.

[16] The use of new tooling technology (namely advances in cutting tools) allowed this advancement in standardised and interchangeable parts (J. P. Womack, Jones, & Roos, 1990).

[17] Production and industrial engineers took care of tooling, quality and component supply (J. P. Womack et al., 1990).

Liberator bomber had dropped from one per day to one per hour (Holweg, 2007; Strategos, 2011; Lean CEO, 2011; Emiliani, 2006).

Ford's ability to achieve continuous flow was not matched with the ability to manage his giant enterprise. He also only offered very limited choice and that choice, the Model –T, remained little changed for its 19 years of production. When Alfred Sloan came to the helm of General Motors in the early 1920's he put the finishing touches on mass production. Sloan brought in a decentralised management system and offered a five-model automobile range that incorporated standard components but also had an annual facelift. When Sloan took Ford's system of production and complemented it with his management and marketing, mass production as a manufacturing strategy was born. Adding to this the advent of organised labour,[18] the United Auto Workers Union of 1930, bought mass production to its mature form (Farber, 2002; Lean CEO, 2011; Ohno, 1988; J. P. Womack et al., 1990; J. Womack, 2004).

Europe was slow to pick up the practices of mass production. However, by 1955 the mass production manufacturing strategy that had been initiated in America had been adopted worldwide and was being used by manufacturers all over the globe. The American based automotive manufacturers Ford, General Motors (GM), and Chrysler had lost the competitive advantage of their mass production systems. Europe also brought new variety to the automobile market and in the 1950's they had lower wages than their American competition. Thus, the European manufacturers experienced export growth as the Americans had earlier. Europe then developed similar labour problems to the American manufacturers; workers became unsettled with the monotony of mass production. Compensation came in the 1970's in the form of more wages and less hours for the workers in Europe. This brought America and Europe to a more level playing field; the automotive mass production sales war was to be fought on product features (J. P. Womack et al., 1990).

2.2.2 Japanese Manufacturing

By the 1970's things were changing again, Japan had entered the competitive automobile manufacturing market in a real way. Japanese manufacturing, once famed for producing poor quality, had by then become a fierce rival to the West as a quality producer and wasn't looking like they were slowing down (see Figure 7). Aspects of culture and socio-political factors unique to Japan were commonly considered by the West as the source of the rise of Japanese manufacturing. What the West needed to come to understand was that the rise of Japanese manufacturing actually was the result of best practice (Cusumano, 1988; Schonberger, 2007).

Western influence was beneficial in the advance of quality in Japan post war. For example, Edward Deming and Joseph Juran supported the effort when called on by Japan in the 1950's. *Training Within Industry* (TWI) was also influential (Huntziger, 2012). TWI is a workplace training programme promoting employee involvement that developed in the United States due to labour shortages of the war efforts. It was spread post

[18] Ford's offering their workers double the ordinary wages in 1914 contributed to the labour unions rise. As worker retention was achieved those retained workers eventually became unsatisfied with the conditions (J. P. Womack et al., 1990).

war to Asia and Europe. It has been called the foundations of lean (Dinero, 2005). However, outside help in itself was not the factor that produced manufacturing excellence in the lean TPS (although it no doubt did help and may have received much of the credit at the time).

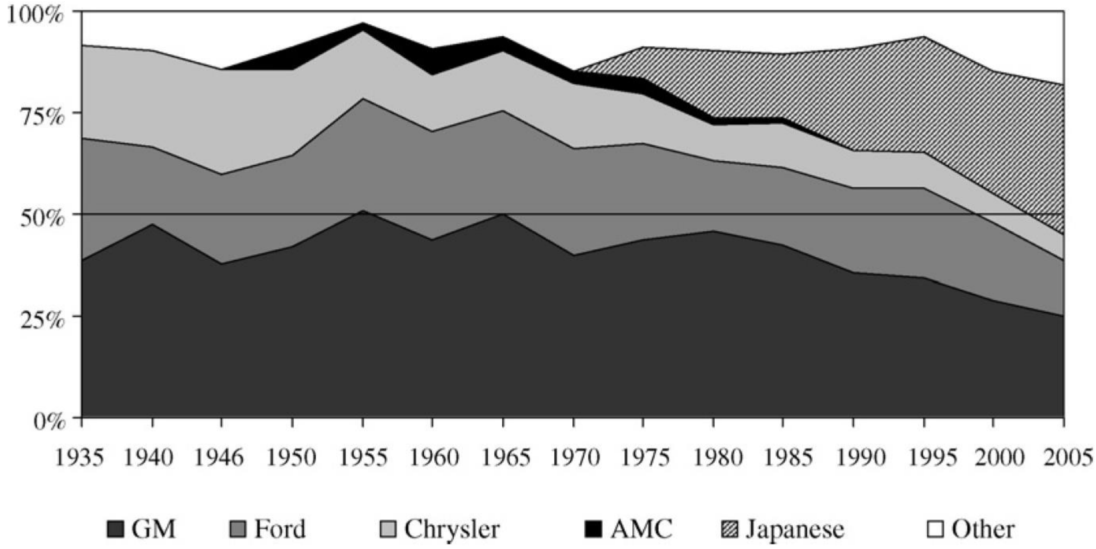

Figure 7 U.S. passenger car market share by company, 1935–2005, (Holweg, 2007). (Image reproduced with permission)

Japan's ability and willingness to assimilate, advance and combine these tools was the real secret to their success (Emiliani, 2006; Schonberger, 2007; Ohno, 1988). An example is Dr. Kaoru Ishikawa's seven tools of process and quality improvement; and his contribution to Quality Circles that that later developed into the West's small-group improvement activities (Schonberger, 2007). However, the stand out case in Japanese manufacturing (and lean) is the Toyota Production System (TPS): a truly Japanese developed production system. Toyota used assimilation and the innovative application of existing techniques coupled with self-invented ones[19] to come up with a unique system of their own. Other Japanese firms quickly followed Toyota's world class lean practice. These firms adopted the TPS in varying degrees and similarly had varying degrees of success. A degree of success is still success nonetheless and thus by the 1970's Japan was competing not only on price and quality but also variety and delivery; the Japanese automobile manufacturers were competing with the West in a serious way (Ohno, 1988, p. 3; Shingo, 1989, p. 16; J. P. Womack et al., 1990, pp. 47, 68; Schonberger, 2007; Tennant, 2001, pp. 4–6).

The Lean TPS – The Development of the Toyota Production System

The Toyota Production System (TPS) emerged from the observation and experimentation of innovative persons, the environment and the crisis at the time that necessitated it (Ohno, 1988, pp. 13, 75–92; J. P. Womack et al., 1990, p. 49). The leaders at Toyota saw the advances of Ford but also recognised the tremendous waste within mass production systems. Toyota embarked on a journey to produce the "antithesis of American mass production" chaos (Shingo, 1989, p. 83).

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[19] For one example is Just-In-Time as discussed later.

Toyota's beginnings were one of innovation. Toyoda Sakichi founded Toyoda Automatic Loom Works from which eventually the Toyota Motor Company was founded by his son Toyoda Kiichiro. The two pillars of the TPS, autonomation (jidoka) and just in time are attributed to Sakichi and Kiichiro respectively. Through the influence of these great observers and inventors Ohno proposed that Toyota inherently understood what "world class" was (Ohno, 1988, pp. 76–78).

Sakichi was a great observer and out from this observation he flourished as an inventor and became a pattern to Taiichi Ohno. Taiichi Ohno, who can be credited with the creation of the Toyota Production System (Shingo, 1989), developed the tool *5 Whys*[20] from Sakichi's habit of watching (Ohno, 1988, p. 78). The concept of jidoka or autonomation then came from Ohno's own observations of Sakichi's inventions. Ohno worked at the Toyota Loom Works from 1932 to its disestablishment in 1943 (Ohno, 1988, p. 76). There he observed the Toyota-type auto-activated loom. The Toyota-type loom was not only powered but also had fault finding function that stopped the loom whenever a thread broke or ran out. This notified the operator and also stopped any wasted production. This type of invention inspired Ohno's development of Jidoka, or as he in his English text (Ohno, 1988) called autonomation i.e. automation with a human touch. The TPS production is halted if defects will occur in order to eliminate waste, inconsistency, and overproduction.[21] Sakichi passed onto Toyota the principle of building this kind of "human intelligence" into machines (Ohno, 1988).

Kiichiro Toyoda grew up in the Toyota loom manufacturing plant and learned at the feet of Sakichi his father. In 1910, Sakichi had been to America and was impressed with the automobile. In 1930,[22] Kiichiro too travelled to Europe and America to arrange the sale of patents of the auto loom for £100,000. It is thought that this money was then used to fund the Toyota research into automobile manufacturing (Holweg, 2007; Ohno, 1988).

As mentioned earlier, the TPS came from observation, innovation, and environment. In regards to observation, Toyoda Kiichiro announced in 1933:

> *"We shall learn production techniques from the American method of mass production. But we will not copy it as is. We shall use our own research and creativity to develop a production method that suits our own country's situation."*
>
> (Ohno, 1988, p. 91)

It is said that Toyoda Kiichiro later proposed "the best way to work would be to have all the parts for assembly at the side of the line just in time for their use" (Ohno, 1988, p. 75). Ohno himself became quite

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[20] A lean root cause analysis method of asking the question "why?" five times to find the deeper solution.

[21] Shingo had a slightly different view of autonomation. He understood the "two characteristic notions" of the TPS as being, "Non-stock production" as seen with JIT and "labour cost reduction" of which autonomation is one of many methods that can achieve this (Shingo, 1989, p. 161).

[22] Holweg (2007) states 1929.

attached to this idea of just in time manufacture. Ohno also pointed to Kiichiro's sound perception of providing value for the customer, and recognising the importance of sales in manufacturing. Additionally Ohno attributed Kiichiro with having a "chess players view" studying the whole picture and constantly developing and reviewing strategies, as also Sakichi his father (Ohno, 1988).

In the 1930's Toyota had wanted to make a passenger cars but efforts were thwarted, Toyota was directed to manufacture trucks for the war effort (J. P. Womack et al., 1990). However, after the war their passion for the automobile bore fruit again. In 1945, Kiichiro Toyoda set the charge to catch up with American automobile manufacturers in three years. This was to enable the survival of the Japanese automobile industry (Ohno, 1988). However, due to a drop in sales, associated labour struggles and a substantial layoff; Kiichiro soon resigned and Eiji Toyoda took his place. In 1950, Eiji visited America and reported that there were possibilities to improve on the mass production system there. Eiji and Ohno realised quickly that the American mass production system would not work in their situation; the Japanese market and post war economic climate. Eiji worked with Ohno to develop Toyota's own production system. The system needed to produce a large variety of vehicles for a relatively small market. One challenge was a workforce that demanded specific rights as required by the post war government under American influence. The labour pressure mounted so far as the requirement of life time employment. One other challenge soon became a blessing, buying extra time for the Japanese manufacturers. This challenge was that the overseas mass producers wanted to take a foot hold in Japan. The Japanese government intervened passing a "prohibition on direct foreign investment in the Japanese motor industry" (J. P. Womack et al., 1990, p. 50). Thus, Toyota and the other emerging firms had time to catch up. Japanese creativity and experimentation was developed the production system at Toyota and over time revolutionised manufacturing, realising autonomation and just in time (Ohno, 1988; J. P. Womack et al., 1990; Holweg, 2007).

Ohno's experimentation included developing quick change over dies for sheet metal presses. The simple flexible machinery that Kiichero had purchased was used to provide the variety of components and models they required. Eventually SMED (Single Minute Exchange of Dies) was developed as supported by Shingo in 1955 (Holweg, 2007; Shingo, 1989). The three minute die changes were revolutionary compared to the hours required in conventional machinery. Ohno also trained his production staff to make these changeovers rather than having dedicated teams. This was part of the softer side of management with the respect for humans and the move towards more skill of production workers; not craftsmen but skilled production staff (J. P. Womack et al., 1990; Krafcik, 1988). The quick change overs also proved the benefit of small batch sizes and their effect on flow.

In 1947, Ohno developed flow in the machine shop and advanced it to reach the assembly line by 1950. He lined up machines one after the other passing parts from one operation to the next as they were completed, rather than building of batches of components. The later method (common practice of the craftsmen era) developed batches of inventory (waste) all over the work shop as well as delays whilst batches were completed before transport (along with other forms of waste) (Ohno, 1988; J. P. Womack et al., 1990;

Holweg, 2007). Flow had been achieved, along with the reduction of inventory, to produce variety in small batches. JIT was soon to be realised, however another tool was needed.

Kanban, integral to the JIT pull system, came from considering the American supermarket in the late 1940's. Observing the supermarket revealed that goods were taken from the shelf at the rate of customer demand; shelves were only replenished once goods had been taken. There was no carrying and peddling of what the customer didn't need as seen in the Japanese system of door to door sales. Ohno realised this leant itself to manufacturing and eventually developed kanbans (cards/bins etc.) as triggers for replenishment of stock for a forward process[23] and in 1953 implemented this system in the machine shop he managed. In this system no excess inventory was require, once a process ahead was depleted of work it pulled from the process behind. Excess inventory was produced to maintain economies of scale or because to fill excess capacity. Instead, components were only processed downstream demand. Kanban had functioned to connect processes into a flow. This was similarly to what was achieved by Ford but Ohno also removed room the buffer stock; the system had become fragile without room for error. This meant, another mechanism was needed, a way of removing defects in the process to achieve smooth JIT manufacture (Ohno, 1988; J. P. Womack et al., 1990; Holweg, 2007).

Ohno used his workers to move the Toyota Production process towards perfection. Workers were placed into teams with a team leader rather than having a shop foreman. The leader arranged the team, assisted in assembly, and provided capacity when the team was short of staff. The teams were given assembly steps to follow but also time to consider improvements (what in the West became quality circles and small group improvements). When a problem occurred, teams were encouraged to find the root cause and empowered address it. Ohno encouraged asking why 5 times, i.e. the 5 Whys tool to find the deeper cause of a problem. In this way, the production team moved the system to perfection by incremental improvements (kaizen). Responsibility for basic tooling and quality was then given to the teams. Developing the quality function of workers meant they were given authority to stop the production line; to stop reproduction of error and waste as it occurred. With safety stock removed from the system, process problems surfaced and the teams addressed them; progress to perfection was being made with continuous improvement, not by an industrial engineer but by the assembly staff (Ohno, 1988; J. P. Womack et al., 1990; Krafcik, 1988).

Some other aspects of note were attention to the identification of waste, and the use of standard work and visual systems. With the onset of the Korean War in 1950, and the pending oil crisis, much drive was given to creating flow with minimal waste. Waste in Toyota's system was identified as room for improvement; productivity = work - waste. Ohno set to reduce the waste to increase productivity. Non-value added activity, waste, was defined by 7 categories: overproduction, waiting, transportation, processing, inventory, movement, and making defective products (Ohno, 1988). As skilled workers were sent to war it became necessary to develop worksheets to achieve standard work with consistency and quality. Standard

[23] See pp 29 & 30 of Ohno (1988) for more detail on Kanban including that itself was a tool for continuous improvement with the rule of seeking opportunity to reduce lot size. Also see Liker (2004) pp. 106, 110.

worksheets in the TPS were another product of their specific environment. These worksheets incorporated visual control (Ohno, 1988, p. 22) which became a big part of TPS and lean systems i.e. visibility of process and progress to all involved.

In 1962 Toyota was ready, kanban been introduced companywide and flow had been achieved between departments; the tool of JIT could now be implemented. Toyota's development of principles, tools, and techniques had been driven by the situations they were in; particularly the supply and financial restraints of the Korean War and the following oil crisis. These environments restricted them to produce only what was required when it was required, and they developed the systems to do so. The low waste lean system was now ready to be presented and taught to Toyota's suppliers; the TPS further propagated. In 1978, Ohno wrote that the TPS had become a uniquely Japanese production system (Ohno, 1988, p.74, translation of the 1978 Japanese edition).

A Further Advancement from Ford and Sloan

Ford's achievement was outstanding in the aspect of standardised parts and flow, however he had some way to go in regards to perfection, even when coupled with Sloan's mass production management system. This was especially noticeable as the market around the automobile industry changed. Flow was achieved by Ford but without the inherent flexibility as see in the TPS which offered different products to different customers; realising what value was to the customer.

> *"The world has already changed from a time when it could sell everything it produced to an affluent society where material needs are routinely met.… We are now unable to sell our products unless we think ourselves into the hearts of our customers each of whom have different concepts and tastes. Today the world has been forced to master in earnest the multi-kind small quantity production system."*
>
> (Ohno, 1988, p. xiv)

There was also much waste in the Ford-Sloan system.

> *"All kind of waste occurs when we try to produce the same product in large homogeneous quantities."*
>
> (Ohno, 1988, p. xiv)[24]

Toyota however had arrived at the lean TPS; they produced "faster and more" through continuous flow.

> *"...we explained the concept of small lot sizes and quick setup. Actually at the heart of this is our intention to reform the existing and deeply rooted concept of 'faster and more' by generating a continuous work flow."*
>
> (Ohno, 1988, p. 109)

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[24] Taiichi Ohno was not critical of Ford but of those who followed blindly to create production systems that because of their design produced much waste (Ohno, 1988, p. xiv).

The leaders at Toyota saw Ford and the western methods of production, and learned from them, but did not duplicate them; they did not and could not afford to duplicate the waste.

Although some have criticised early praise of the Japanese management styles (Woronoff, 1991), what happened at Toyota was the greatest leap to lean thinking and revolutionised the mass production mind set. Innovative minds, through much observation and experimentation, took existing techniques along with the invention of their own methods to hybridise a manufacturing strategy (Fujimoto, 1999) that is seemingly unprecedented in history. The study and documentation of their practice has been referred to as the "decoding the DNA of the Toyota Production System" (Spear & Bowen, 1999); this indicates the powerful nature of being able to understand the intricacies of the TPS.

In 1987, Taiichi Ohno wrote:

> *"The Toyota production system, however, is not just a production system. I am confident it will reveal its strength as a management system adapted to today's era of global markets and high-level computerized information systems."*
>
> (Ohno, 1988, p. xv)

With the help of the researchers, like those at the International Motor Vehicle Program, unravelling the hidden secrets of the success of the TPS (Holweg, 2007), the truth in Ohno's statement can be realised along with its foreshadowing of *lean thinking*.

2.2.3 Noticed in the West

There was some interest in Japanese manufacturing from the early 1970's but the TPS stayed unnoticed as a factor until later in that decade. The TPS knowledge propagated initially with the writing of Sugimori (1977) and Ashburn (1977). It seems that that the oil crisis of 1973 was the factor that increased interest in Japanese manufacturing and the TPS. In the hardships of 1970's, whilst manufacturers (including Toyota) struggled to make profit; the lean system that Toyota had developed gave them success compared with Western manufacturers. In 1979 Ezra Vogel's book, Japan as Number 1: Lessons for America (Vogel, 1979), even if incorrect (Woronoff, 1991), further advertised the success of Japanese industry and led to an advance of academics, consultants, CEOs and other professionals seeking the secrets of Japanese manufacturing (Schonberger, 2007; Holweg, 2007; Ohno, 1988).

Compendex searches for Japanese manufacturing and related TPS terminology show little references to Toyota or Japanese systems between 1950 and 1980. This period only revealed a handful of articles of any relevance. The quantity of references found by adjusting the search beyond 1980 indicates the topic of Japanese manufacturing and TPS and its associated tools and techniques were beginning to be investigated more and more widely in the west. In 1977 the western world had got wind of the advances of the TPS (Ashburn, 1977; Sugimori et al., 1977), and received further information on the unique Japanese style in 1979 (Vogel, 1979). Further study and the initial implementation followed from the early 1980's (Schonberger, 2007), with particularly strong cases in Connecticut (Emiliani, 2006). But the thought that the

West had little to learn from Japan remained strong until the evidence of the International Motor Vehicle Program (IMVP) was publicised. Discussions at that time considered other factors as the means for Japanese success; cultural differences, luck,[25] perceived lower costs, high levels of automation, orchestration from the Ministry of International Trade and Industry, and government policies. The fact that Japan might have stumbled on a manufacturing system superior to the one of the west had been given little thought (Hines et al., 2004; Holweg, 2007).

The International Motor Vehicle Program

Besides the IMVP there has been other good and in-depth studies on Japanese manufacture, JIT and the Toyota Production System (Fujimoto, 1999; Osono, Shimizu, & Takeuchi, 2008; Spear & Bowen, 1999; Wakamatsu, 2009), including studies that preceded the IMVP (Ashburn, 1977; Munzberg, 1984; Schmitt & Connors, 1984; Schonberger & Gilbert, 1982; Schonberger, 1982a, 1982b, 1983; Sugimori et al., 1977). The author however observed that the outputs of no other study appeared to be as popular and prevailing in reference, recommendation on websites and forum, and in general or perceived effect on the world stage, than the publications with roots in the IMVP study. From the IMVP has come the distilled lean thinking of defining value, mapping the value stream, creating flow and implementing pull unto perfection (discussed earlier).

In 1985,[26] following a five year study on The Future of the Automobile, the International Motor Vehicle Program (IMVP) found funding and was further initiated at MIT. IMVP started as part of the new MIT Center for Technology, Policy, and Industrial Development. The centre had the charter to *"go beyond conventional research to explore creative mechanisms for industry-government-university interaction on an international basis in order to understand the fundamental forces of industrial change and improve the policy-making process in dealing with change"* (J. P. Womack et al., 1990, p. 4). It was realised that IMVP success would come from *"thoroughness, expertise, a global outlook, independence, industry access, and continuous feedback"* (p. 4). This study set out to go further than those who had gone before. The program succeeded specifying new metrics for measurements and comparison, using an international team of researchers, gaining access to automobile manufacturers all over the world, and access to staff at all levels (J. P. Womack et al., 1990; Holweg, 2007).

In order to do a fair comparative study of assembly plants a new methodology was needed. There was an understanding of the different manufacturing practices but how to measure the differences was undefined. As Dan Jones commented, "*we had a method but no methodology"* (Holweg, 2007). Initial techniques were developed by Womack and Jones and trialled in 1986, however these were expanded on by John Krafcik.

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[25] Lucky that the smaller automobiles manufactured in Japan met the efficiency needs of the oil crisis better than typical Western automobiles.

[26] Holweg (2007) puts the start of the IMVP at 1979 coinciding with the start of the study on The Future of the Automobile.

John Krafcik had shop floor experience in the automobile industry and used this to aid development of the new metrics. Examples of metrics used for standard comparative measurements are: the amount of area used for rework, number of spot welds in a car (i.e. to determine standard vehicle size) and the number of options in assembly. When the initial performance comparison results were displayed the difference between the Japanese style system and the prevailing western methodology was so disparaging to the western sponsors that many of them suggested the data needed review; a few in their foresight were encouraged that they would soon get the help they needed. By 1990, the study had gone much further in the level of detail and presentation. The study had also stretched beyond the assembly plant. *The Machine that Changed the World* (Holweg, 2007; J. P. Womack et al., 1990) was the seminal text that presented their findings.

A Book: The Machine that Changed the World

> *"The global assembly plant data was undoubtedly the empirical backbone of IMVP, yet as Dan Roos argues, the 'Machine' crucially showed that lean was 'not just manufacturing, but in fact a holistic logic and management system that starkly contrasted with the traditional mass production approach'*. The 'Machine' provided a much more comprehensive yet technically far less detailed picture of the Toyota Production System than previous books, and it included issues such as supplier management and product development."*
>
> (Holweg, 2007)

In 1990, the book *The Machine that Changed the World* (J. P. Womack et al., 1990) was released as a product of 5 years of the IMVP. In authorship, effort was made to produce a book on lean that would be a direct contributor to lean knowledge saturation in industry as opposed to merely having an academic contribution (Holweg, 2007). The effect of this publication was wide spread and noticed in New Zealand (Joiner, 2011). A key factor to the influence it had was the comparative research methods, the support of the IMVP research with in quality and quantity. One of the key challenges of the book was to separate in the western psyche the success of lean techniques from association with a Japanese phenomenon.

> *"In presenting our work to a broad audience we have one great fear: that readers will praise it or condemn it as yet another "Japan" book, concerned with how a sub-set of population within a relatively small country produces manufactured goods in a unique way. Our intention is emphatically different. We believe that the fundamental principles of lean production are universal – applicable anywhere by anyone – and that many non-Japanese companies have already learned this."*
>
> (J. P. Womack et al., 1990, p. 9)

This thoroughness and informal (or less academic) authorship allowed a breakthrough in the scepticism surrounding prior research and seeming denial that the Japanese might have stumbled on a superior production system (Holweg, 2007; Schonberger, 2007; Hines et al., 2004; Schmidt, 2011; J. P. Womack & Jones, 2003). This book proved to industry the Japanese systems success and efficacy was relevant also in the western world. *IMVP measurements showed not only a performance gap between Japan and the West but presented measures that specified the size of the gap more clearly*. It also *proved it was possible to have American factories with American workers be a high performing lean enterprise* and on the other hand showing Japanese firms that were lagging behind. The key factor to this presentation was the New United Motor Manufacturing (NUMMI) joint venture between GM and Toyota. NUMMI was established in 1984 at an old GM plant with its previous (American) employees. Krafcik, a researcher who had worked at the plant, possessed the before and after data for the GM Freemont plant that became NUMMI.[27] Early in the study Krafcik presented a paper at a 1986 policy forum, which was titled 'Learning from NUMMI'

> *"The paper showed that NUMMI, within its first year of operation, had achieved a productivity level more than 50% higher than that of the technologically similar Framingham plant, and achieved the best quality within GM's entire U.S. operation. These results were particularly powerful, as NUMMI was a former GM plant that had been closed in 1982 after severe industrial action, but largely reemployed the same workforce and did not use any significantly different or new technology."*
>
> (Holweg, 2007)

This type of result showed a gap in performance that was not a purely Japanese phenomenon but rather the result of a superior system. The West needed to close the gap by learning from these systems. What was lacked in industry was the "how to" of lean. (Holweg, 2007; J. P. Womack et al., 1990; J. P. Womack & Jones, 2003)

Introducing the "How To" of Lean

The initial "how to" of becoming lean was recorded in 1996; Womack and Jones' book *Lean Thinking*. In trying to understand the "how to" of lean implementation, they decided to self-fund a 4 year longitudinal study of 50 selected firms. The motive to this was important: their desire was not to get the average opinion as a typical broad survey style of research, the average opinion of all lean practitioners. Womack and Jones chose to find exemplary examples of lean practice and from these determine what principles were essential to lean thinking. To do this they researched firms and engrossed themselves in these firms' environments. They also added to their experience by developing a financial and therefore strategic interest in a manufacturing firm. The first edition of Lean Thinking was released in 1996. The second edition to the book was released in 2003 following fluctuations in the economy and reported further developments. The second edition included developments in the case studies and others critiques of the first edition, and confirmations and further defence of their conclusions. As well as the cycle of defining value, mapping the value stream, creating flow, and implementing pull the book discussed extended mapping of the value stream; looking at

[27] As NUMMI was a new joint venture established at an old plant with many of the original workers, but not all, it is difficult to say whether it is a case of a lean implementation/ transformation of a brownfield or the establishment of lean in a greenfield situation.

the suppliers beyond the suppliers and the waste created throughout. For example, the value stream from the iron ore mined through to the consumer of a steel product (J. P. Womack & Jones, 2003).

Coining of the Term "Lean"

Some find the term *lean* off-putting and consider lean as *mean* manufacturing and another term for reducing expenditure by reducing staff numbers. In some cases, practitioners choose to develop their own terminology e.g. "The Shamrock Production System" for a manufacturing company named Shamrock Industries (J. P. Womack & Jones, 2003; Gardiner, 2011; Joiner, 2011; Reaney, 2011). It is interesting to note the origin of the term *lean* itself.

The term lean was chosen as the opposite to *buffered*; and was first coined by Krafcik during his MBA studies under the IMVP. Lean as a terminology was first presented in Krafcik's 1988 Article *The triumph of the lean production system* (Holweg, 2007; Krafcik, 1988). The article pointed to *"links between high productivity, quality and product quality"* whilst debunking *"myths about national performance"* and that high technology is the solution to increase productivity (Krafcik, 1988). The article included discussion of the span of worker control. Historically, there was a shift worker control from the craftsmen period (craft style production) to *pure Fordism* (where workers had compartmentalised tasks), to *recent Fordism* (a buffered version of Ford's mass production) and then the development of the flexible yet *lean Japanese production* system (where the span of worker control is increased although not to the level of the craftsmen). As mentioned, mass production systems saw buffers as positive as they make a system robust to variation. A lean system, having little or no buffers is somewhat 'fragile'. When errors occur, the frailty is positive because it highlights them and forces an action to correct and improve the process so that the problem does not reoccur. Thus, the worker is given more training, control, and opportunity to identify where fragility manifests. Where defects occur, workers are given opportunity to identify the root cause and implement solutions.

Industries Response

The knowledge of lean significantly developed in the mid 1980's but there was little response from the American automobile industry. Along with NUMMI, there were other Japanese transplant operations in the west and in particular the Toyota's Supplier Support Center (TSSC) in America. The TSSC's development and training of their supplier network coincided with the IMVP study and contributed to lean knowledge saturation in the west. NUMMI and the other transplant operations not only bought attention to the TPS it also gave a local viewing platform; as opposed to having to travel to Japan to see lean and JIT practices in action. Negatively, lean saturation continued to be slow. Even with NUMMI, the various other Japanese transplant operations, the released work of the IMVP, and the 'Machine' book; the West was slow to learn. Even GM's own NUMMI plant was described as a source of shame to their other plant; it should have been their training ground. GM teams were sent to the NUMMI plant, but an adequate knowledge transfer did not take place; GM missed an opportunity for lean transformation (Holweg, 2007; J. P. Womack & Jones, 2003).

2.2.4 Alternative and Hybrid Developments

It is not sufficient to exist in a lean bubble; there has been the development of many alternative and hybrid systems. These developments have similarities with lean and to practitioners of lean are complementary. It is noted that the proprietors of the other methodologies may see lean as unoriginal and as prescribing tools for use in their preferred methodology (Dahlgaard & Dahlgaard-Park, 2006; Nave, 2002). Also, lean can be considered by some as merely an extension of the earlier developing JIT paradigm (Schonberger, 2007) as opposed to JIT as a subservient method to another paradigm, namely lean. Early work was conducted regarding JIT systems, having many aspects common to lean. This included comparisons between uptake in SMEs compared with larger businesses, e.g. White et. al (1999). However, it is apparent that much time has passed and the up-to-date body of knowledge is with lean.

The purpose of this wok was to explore how to improve the implementation of lean. Then in this work, the view was to take other methodologies as subservient tools in a lean implementation: as example, using six sigma in process improvement. This is the amalgamation of many paradigms into one system of world-class manufacturing, or world-class manufacturing and company management (Schonberger, 2007). Womack (2003) states:

> *At the end of the day we are all trying to achieve the same thing: The perfect value stream…* [and] *energy expended on comparing and criticizing improvement methods rather than pursuing the perfect value stream, is surely Type Two muda. That's the type of waste we can get rid of immediately!*

This point of view is accurate, however this work takes the perspective of lean as an overarching strategy.

Kaizen and Continuous Improvement—Concept and Umbrella Methodolgy

Kaizen, is an anglicised Japanese word for improvement, that has come to express either the philosophy or practices of continuous improvement. The term was introduced by Masaki Imai in 1986 (Imai, 1986; Recht & Wilderom, 1998). Although it may be thought of as continual improvement, Imai presented kaizen as "ongoing improvement involving everyone—top management, managers and workers". Imai also presented kaizen as an umbrella concept encompassing many methods, these are typically methods as associated with TPS and lean e.g. customer focus, TQC, JIT and TPM (Imai, 1986; Recht & Wilderom, 1998). Kaizen as a philosophy is propagated much by the Kaizen Institute founded by Imai (Kaizen Institute, 2011, 2014) and their publications (Coimbra, 2013; Imai, 1986, 1997; Miller, Wroblewski, & Villafuerte, 2013). Their websites mixes lean and kaizen together as if they are synonymous.[28] *Continuous improvement* like kaizen could similarly be identified as a body of knowledge in its own right (Bessant, Caffyn, & Gallagher, 2001; Bessant & Caffyn, 1997; Kaye & Anderson, 1999; Suzaki, 1987; Wu & Chen, 2006) but is often used to encompass the whole body of related philosophies and methodologies, e.g. kaizen, TPS, TOC, TQM and lean (Bhuiyan & Baghel, 2005).

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[28] This is possibly due to the prevalence and popularity of lean. Lean may be considered a keyword needed in advertising their consulting services

Kaizen events or *blitzes* are often referred to in practitioner discussions of lean (Baudin, 2012). This is really a stretch of the word kaizen. These events are really kaikaku initiatives as one off events for “radical change” i.e. kaikaku. They are not in the nature of kaizen—everybody, everywhere, everyday improvement.

Total Quality Management (TQM)

Emerging in the 1980’s, TQM developed as an off shoot of Japanese a manufacturing method total quality control (TQC). TQC was a parallel development to the TPS and likewise as the western extensions TQM and lean developed in parallel in the 1990’s. The focus of the term *total* in TQM is that the quality function is carried out by every person in a process. This necessitates a high level of employee involvement, engagement, and empowerment as seen with lean practices. The quality aspects of lean, having employee control, mistake proofing, and process improvement; all show the close association of TQM with lean and the claims of TQM enthusiasts on leans origins (Schonberger, 2007; Dahlgaard & Dahlgaard-Park, 2006).

Six Sigma

> *Treading in the steps of TQM, Six Sigma is a new approach to quality management (Su et al., 2006; Kumar et al., 2008). Six Sigma was initiated by Motorola Inc. in the 1980s and has been defined as “an organized and systematic method for strategic process improvement and new product and service development that relies on statistical methods and the scientific method to make dramatic reductions in customer defined defect rates” (Linderman et al., 2003, p. 195). Some argue that Six Sigma is just a repackaging of TQM (e.g., Stamatis, 2000) and that “TQM makes many of the same claims that Six Sigma makes and with some justification” (Flott, 2000, p. 43). However, recent research suggests that Six Sigma introduces new and distinct concept and practices into quality management*.
>
> (Zu, Robbins, & Fredendall, 2010)

Six sigma, as lean and TOC, has been on a journey. Six sigma is a method for improving processes through statistical means; it was originally developed at Motorola. Although TQM methods play a big part in Six sigma, it is said that six sigma extends further; including vision and goal, moving in the direction of perfection. As a concept, it includes the customer, the process, and the employee. In basic terms, six sigma takes what is important to a customer, in regards to quality, and measures it against acceptable limits. From this the degree of quality is determined; a product of process stability or control. Measurements are compared to the normal distribution. (Antony, 2011; Goh, 2011, p. 7; Nave, 2002; Tennant, 2001)

For six sigma, the aim is zero defects. Typically measurements can be taken and the normal distribution plotted for variations in the process with a target of six sigma; six standard deviations, 3.4 defects per million (Tennant, 2001, p. 7). Six sigma identifies a process for improvement and aims to increase quality and performance, adding value to the customer. The improvement process is defined by the acronym DMAIC: Define, Measure, Analyse, Improve, and Control. The emphasis is with statistical means. Employees chosen for six sigma training need to be competent to drive this statistical method; not be driven by the method. As with lean and other paradigms, six sigma has been wielded as a tool for making consultants profit without proper consideration for the technique and further implications. This has resulted in some uninspiring implementations and negative attitudes to continuous improvement methods. (Goh, 2011; Nave, 2002; Dahlgaard & Dahlgaard-Park, 2006; Antony, 2011)

Six Sigma, TQM and Lean: Quality vs. Flow Focus

It is apparent that whereas six sigma and TQM focuses on maintaining and improving quality; lean focuses on generating flow of value, with the *pull* of that value from the customer (Antony, 2011; Dahlgaard & Dahlgaard-Park, 2006). In the author's (possibly biased) mind, this is where the distinct benefit and power of lean lies. Understanding the six sigma tools can be difficult to learn and implement, and there is some general debate regarding how suitable six sigma is as an improvement methodology. Most problems don't need a complex solution (Heath & Heath, 2010, pp. 44, 45, 71), and therefore six sigma is excessive for the majority of situations. It is possible to get bogged down with this tool where practical problem solving in a disciplined culture is what is required (Liker, 2004, pp. 252–256, 295–296). It was recently reported that lean six sigma (LSS) approaches might be less successful than pure lean implementations (Ngo & Heyl, 2012). It is suggested that six sigma be applied as a tool where suitable; where the process requires a higher level of statistical analysis. For sustainability, it would be detrimental to focus on six sigma analysis in the majority of situations.

Theory of Constraints

The Theory of Constraints (TOC) was introduced by Eliyahu M. Goldratt in his book The Goal (Goldratt & Cox, 1984). Theory of Constraints like lean looks at the whole integrated system rather than parts. TOC, again like lean, disagrees with traditional accounting methods and such practices as calculating inventory as an asset and traditional concepts around economies of scale. It emphasises the constraint in a system, which is like a bottle neck, the weakest link in the critical chain of processes. By identifying the constraint, and exploiting the constraint to improve its capacity, the entire system becomes more productive. TOC describes this as *throughput* going up whilst *operating expense* and *inventory* going down. The constraint becomes the focus for improvement and its pace in turn sets the pace of the entire system. If parts of the system are producing more than the constraint then that is considered as waste, producing inventory faster than the constraint can process it. In *The Goal* (Goldratt & Cox, 1984), statements like *"a factory in which all the workers are busy all the time is a very inefficient factory"* help to adjust the concepts of the reader. The reader is led to see the waste of running production without seeing the wholes system. (Goldratt & Cox, 2004; Nave, 2002)

The overall goal of a business[29] is to make money thus TOC stresses that the three measures critical to this are: throughput, operational expense, and inventory. In order to improve these metrics the below method is used:

1. Identify the constraint (i.e. what hinders the enterprise from obtaining the goal).
2. Decide the method for exploiting (getting the most out of) the constraint to increase the capacity and productivity of the whole system.
3. Subordinate all other processes to support the constraint.
4. Elevate the constraint (improve the constraining process to increase production of the whole).
5. Return to Step 1 (continuous improvement).

Buffers are used throughout the Theory of Constraints systems; however, there is an emphasis on reducing their size. Buffers often result as part of the exploit and subordinate steps of the five focusing steps. To keep the constraint at full capacity buffers are placed before the determined constraint. These buffers are kept appropriately small to ensure flow through the system. Viewing the system in this way adjusts the thinking of setups wasting time. If a machine is not the constraint it has spare capacity, so in many cases an extra setup doesn't actually cost anything but only uses an operators idle time (Goldratt & Cox, 1984; Nave, 2002).

One particularly different characteristic of TOC is the lack of emphasis on employee engagement (Nave, 2002). This is as opposed to other the methods (Lean, TQM, and six sigma) whose roots are more directly identifiable with Japanese manufacturing. TOC tends to a more top down approach. In fairness, the Goal (Goldratt & Cox, 1984) with its various editions (Goldratt & Cox, 2004) does not neglect employee contribution altogether. The text points towards placing the higher skilled labour at the constraint; thus ensuring the ability for problem solving and improvement is at the bottleneck for the system. However, this was noted at the team leader rather than line worker level.

The author believes that *The Goal* (Goldratt & Cox, 1984) is very useful in getting its audience to begin to see the whole system, lose interest in traditional focus on economy of scales and see the benefit of reducing batch sizes, and increase throughput of the whole system. Such concepts are important to lean thinking and this text is useful for training.

Agile Solutions

As a response to the mass production paradigm and its ability to cope with variability along with similar critiques of the developing lean paradigm, Agile solutions were developed (Kettunen, 2009; Hines et al., 2004). Agile is attributed with fast response times, flexibility and adaptability to changing circumstances, the use of virtual corporations, ability to reconfigure organisations, dynamic teamwork and knowledge

[29] It is agreed that many businesses are not for profit as their main goal (Nave, 2002). However given due care for ethical considerations is taken, the far greater percentage of businesses exist for producing a profit.

transformation (P. T Kidd, 1995). Agile is novel in that it develops virtual supplier network relationships for quick response times. Agile methodologies were also developed and particularly well assimilated in management of software development projects. Kettunen (2009) suggested that the agile software (AS) branch appears to have links with agile manufacturing (AM) and the current incarnation could be benefited from the manufacturing variant. It is reasonable that as AM can learn from AS, lean can learn and adopt from AM, AS and any other variant; adopting useful tools. For early contributions to Agile see Kidd (1994), and Goldman *et al.* (1995).

Systems Thinking

> *"The key… is not any of the individual elements… [but] having all the elements as a system."*
>
> Fuji Cho (Liker, 2004, p. xv)

Systems thinking or systems science is science taken as a whole rather than a part (Ackoff, 1972, 1981). This is particularly relevant to lean and similarly TOC in the aspect of flow thinking. Systems thinking is represented in Ohno's (1988) statement that optimisation should be for the flow of material not the efficiency of persons or equipment. Making one part of a system less efficient may actually provide greater efficiency for the system as a whole; for example, a dumb waiter reduces the size and function of a kitchen but improves the function of the house as a system (Ackoff, 1972, 1981, 2003). In lean sometimes a decision that seems to add waste may actually improve the overall system efficiency, for instance stopping a machine (Liker, 2004, pp. 8, 9). See also McGowan (2011).

Technology Advances: ERP

In the past decades, there has been much advancement in technology. Personal computers are readily available to the consumer and industry, along with a plethora of automation, robotic solutions, and tracking technology. Enterprise Resource Planning (ERP) solutions are particularly prevalent technology in manufacturing. ERP is a software based solution developed as the extension of Materials Requirement Planning (MRP) to include accounting and marketing and other foreseeable aspects of a business. ERP is the spread of MRP technology to not only be materials and manufacturing planning but include all of the business processes. This aims to replace disconnected data silos and reduce duplicated data entry; enabling greater control, integration and reporting. The use of ERP becomes a competitive advantage in streamlining tasks and makes business information readily accessible. These extensive banks of consolidated data can also be mined for marketing (Hill & Lewicki, 2005) or other purposes. (Robert Jacobs & "Ted" Weston Jr., 2007; Daneva & Wieringa, 2005)

As MRP was associated with typical batch and queue, build to forecast techniques, ERP has been considered not applicable to lean. Forecasts are inaccurate and it is not ideal to operate in batch and queue mode; however, that does not mean technology should not be used in lean. The many metrics that can be calculated in ERP solutions can be beneficial to measure and even visually report KPIs as well as capacity planning. Necessarily the selection of the right software solution for a particular situation is critical as some systems can be inflexible. In lean, ERP and software in general is seen as another tool that can be utilised where deemed appropriate. (Hines et al., 2008, p. 83; J. P. Womack & Jones, 2003, pp. 70, 265; Daneva & Wieringa, 2005)

Integrated Thinking

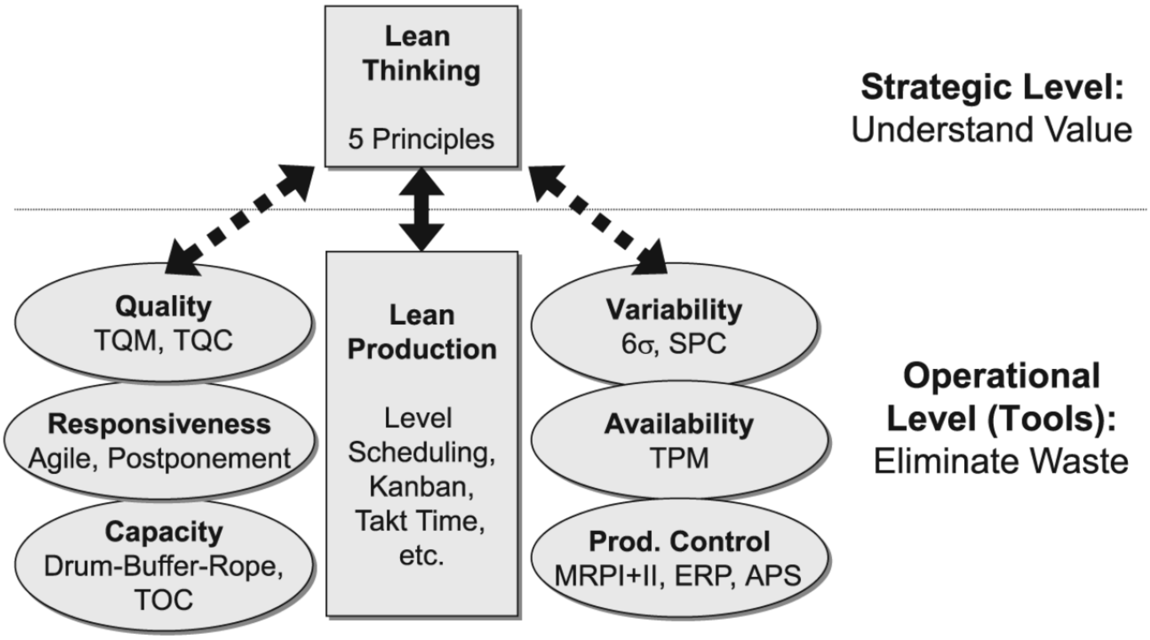

Figure 8 The strategic level of lean versus the operational level of lean. This figure shows various tools available for use at the operational level. Figure from Hines (2004) reproduced with permission.

The alternative methods can be applied in lean operations. It is suggested that they be applied as tools at an operational level. Strategically, the five principles of lean thinking can be upheld: defining value from the customer’s perspective, mapping the value stream, flowing value, implementing pull systems and continuously improving with the goal of perfection. However, at an operational level a myriad of tools could be used. Traditional TPS/JIT/lean tools exist and technology advancements can be applied. In addition, the parallel and alternative paradigms like TQC, TOC and six sigma can be applied as methods subservient to lean, the governing business strategy. This is illustrated in Figure 8. It is important to have an understanding of lean at the strategic level, and then at an operational level the tools are used to empower staff and eliminate waste in the system. (Hines et al., 2004)

Special attention to standard terminology may be important in a hybrid system. For example, a quality function and a lean deployment function in the same firm may be speaking about the same concept using two different terms; this creates confusion. The quality function could be merged with the lean function as the governing strategy (J. P. Womack & Jones, 2003, p. 257).

2.3 Critiques of Lean

Lean itself has been on a journey of development since the concept was initially defined in the 1990's. The following critiques of lean practice are useful, they show the confusion created as lean has developed.

2.3.1 Is Employee Engagement a Myth?

Employee engagement in lean enterprises has been said to be false. This is really an early critique of lean in the 1990's that was brought forward. Take the example of Crute et al. (2003) who candidly pointed to Delbridge (1998) and then a comment by Terry Smith; business representative with the International Association of Machinists (MAN NEWS, 2000).

> *This definition of lean is a way of thinking rather than mere tools; lean could be considered a culture. Undoubtedly, as Womack et al. (1990) predicted, Lean practices have crossed from the automotive sector into other industries. However, the Lean paradigm is not without its critiques. For example, Delbridge (1998) is very critical of supposed benefits of team working and empowerment promised by the adoption of Lean practices and argues that these are based on myth. These views have some support in the aerospace sector, as the following quote illustrates:*
>
> > *"Lockheed's version of Lean manufacturing isn't with employee empowerment", says Terry Smith, a business representative with the International Association of Machinists and Aerospace Workers (LAM) at the Ft. Worth plant. "Their version of Lean manufacturing is more top down where they say, 'We want you to do it this way so we can figure out how to do it cheaper and with less people'" Manufacturing News. (April 10, 2000 p. 3)*
>
> (Crute et al., 2003)

In review of the references (Delbridge, 1998; MAN NEWS, 2000), the author believes that there is little potency in the above statements, and recognises this was not the major part of Crute's contribution which was overall positive to lean.

Regarding Delbridge, his book was entitled Life on the Line in Contemporary Manufacturing. Released in 1998, it was well written and presented insight into life on the production line through his observations as a production worker in two enterprises. However to offer a serious critique of lean on the research in this book alone would be premature. The case study was done in 1991 and extended for 3 months at one enterprise and four weeks at the other (IND REL, 1999). In 1991 the West was only beginning to realise the benefits of lean as presented by the Machine book (J. P. Womack et al., 1990) and it wasn't until 1996 that further literature on how to implement lean was clearly available; that is the first edition of *Lean Thinking* (J. P. Womack & Jones, 2003). Also, this period of lean history was characterised by quality driven initiatives (Hines et al., 2008) as seen in the Delbridge's work. In this book, contents came from two short stints on production lines and the view of a social scientist into the manufacturing world. This study points out many insights into two enterprises that are apparently struggling to implement lean; these insights are helpful and sighted elsewhere in this work. However, the extent to which these two enterprises have moved along the journey of continuous improvement since may be quite significant. So firstly, their success with engagement of their employees is likely to be quite different also. Hence, the comments in this book regarding lean engagement being an ideology and not working in practice (Delbridge, 1998, p. 178) are somewhat premature. Additionally, at three months on one production line and two weeks on the other, the case study of two is insightful but not nearly longitudinal or current in regards to lean engagement.

Regarding the confirmation of Delbridge by Terry Smith, it is hard to take his recorded comments with much weight when considering the context. Smith made these comments as a business representative of a union on strike; whilst attacking Lockheed-Martin's position on wage levels (MAN NEWS, 2000). Establishing the truth of this claim beyond this biased context would require further research.

A similarly themed book, to Delbridge's, is *Just Another Car Factory? Lean Production and Its Discontents* (Rinehart & etc, 1997), a text related to an earlier publication (Robertson, Rinehart, & Huxley, 1992). The book is marked by worker strike actions based on unfulfilled promises regarding labour conditions. This is an excellent study on CAMI, a poorly performing Japanese transplant, a joint venture between GM and Suzuki. It however is extremely questionable that the authors use the study of this plant to be critical of lean, especially in light of the thorough comparisons made in the IMVP study at MIT. In hindsight, a better and acceptable fiding of the study would have been that, it was not clearly understood how to gain the benefits of the TPS and this needed further investigations.

2.3.2 Does Lean Practice Exploit and Apply High Pressure to Employees?

Because of the aspects of human engagement and empowerment, lean can be viewed as exploitative and exerting high pressure on staff. That is, as employees are engaged and empowered their responsibilities increase dramatically e.g. for quality control and process improvement. There is also peer to peer pressure due to performance dependency in the flow line scenarios common in lean production. Hines (2004) points to Garrahan & Stewart (1992) and Williams et al. (1992) as the chief critics. These aspects also were noted by Delbridge (1998). As with the previous mentioned critique, it is indicative that these are early-stage lean criticisms. There is not wide spread support for these criticisms but they still stress the need for the respect for humans (Hines et al., 2004).

2.3.3 Does Lean Possess Scope and Strategic Perspective?

Lean has also been criticised as having a lack of scope and being without strategic perspective. Many lean programmes prescribe tools for implementation rather than the full spectrum application of lean thinking (Hines et al., 2004). Lean is often taken as tools and methods alone (J. P. Womack, 2007). These project based process improvements do lack scope and strategic perspective but do not represent real lean. Real lean exhibits true kaizen for value creation, these can be integrated into a holistic lean system.

2.3.4 Can Lean Cope With Variability?

The ability of lean to cope with variability has been criticised. An over emphasis on kanban as a tool, rather than pull as a developed system, is the source of this negativity. This has led to the development of *agile* solutions. These solutions have greater emphasis variation in demand and the need for flexible assemble-to-order systems, creating virtual supply chains, and elevating use of IT tools. Outsourcing techniques coupled with lean practice do come part of the way but possess their own difficulties, risks and challenges; for example knowledge diffusion, disruption and abuse of information. Techniques for manufacturing flexibility, e.g. Agile solutions, are a key topic for contemporary lean practice (Hines et al., 2004; Todd A. Boyle & Scherrer-Rathje, 2009).

2.3.5 Does Lean Possess Contingency?

Lean has been criticised for lacking contingency; specifically as it has diverged from the automobile, mass production world (Crute et al., 2003). This critique is not just common to lean but to other management practice also, as recorded by Sousa & Voss (2008).

> *Simultaneously, the OM* [operations management] *practitioner literature abounds with reports of problems in implementing best practices (e.g., [Bowman, 1996], [Dooyoung et al., 1998] and [Maddow, 1995]). Although proponents of the universal view of OM best practices would argue that implementation difficulties are part of moving the organization towards "excellence" or "world class status", an alternative explanation is that these difficulties result from too great a mismatch between the proposed form of best practice and the particular organizational context (Sousa and Voss, 2001).*
>
> *Against this background, research in maturing OM best practices has recently began to see a shift in interest from the justification of the value of those practices to the understanding of the contextual conditions under which they are effective. Such research is typically anchored on a contingency approach and examines relationships between contextual variables, the use of practices and the associated performance outcomes. We call this body of research OM practice contingency research (OM PCR).*
>
> (Sousa & Voss, 2008)

Lean was criticised in the R&D industry for being restrictive, too prescriptive, limiting the creativity of staff. This is an example of not understanding the success factors for lean implementation (Johnstone, Pairaudeau, & Pettersson, 2011). This discussion points to two deficiencies. The first is that practitioners do not seek to understand lean properly in themselves and the second that lean needs to be further developed to provide the specific contingency factors for success (Hines et al., 2008, 2004; Sousa & Voss, 2008). Lean is thought to be applicable to all business environments but there are few custom models. New models are needed to make the knowledge readily available and easy to understand.

Literature (Sousa & Voss, 2008; Jayaram, Ahire, & Dreyfus, 2010) points to the following broad contingency factor categories:

1. Firm size
2. Implementation duration
3. Industry type (manufacturing or service)
4. And unionisation

However there are many other subtle aspects that are included in lean contingency, for example management commitments, customer focus, employee environment, training, equipment availability, product processes and product mix (Jayaram et al., 2010; Hines et al., 2008).

2.3.6 Lean Contingency for the SME

Lean and any similar changes are a particular struggle for SMEs. Even if there is willingness at management levels, there is still the need of a change agent and a significant amount of knowledge. Additionally, once the internal knowledge is developed it can quickly deplete with staff attrition. However, with small organisations the ability to see the whole system is a benefit. This and other benefits are discussed by Goodyer et al. (2011):

> *The issue of organisational size is a potentially significant factor in relation to the problems with sustaining improvement initiatives as outlined above. In terms of inherent disadvantages, SMEs in general and by definition have less available resource to devote to non-essential, non-core activities, which often extends to the implementation of operational / quality improvement initiatives (e.g. Prajogo & Brown, 2006). SME staff that do possess expertise in such areas can be quickly recruited by larger organisations who pay more, and this in turn reduces the smaller organisation's incentive to train and develop employees in Lean, six sigma and other very marketable skill sets. On the advantages side, SMEs being flatter and less hierarchical or bureaucratic, find it easier to communicate effectively across functions or processes, and view their systems holistically. They tend to excel in innovation, and have been found to have certain performance advantages such as shorter lead times resulting from narrower product range (Belvedere et al, 2010). Done et al (2011) have recently reported, however, that best practice interventions have limited ability to bring about long-term change within SMEs. This finding is in common with much of the research into improvement within SMEs.*

One of the advantages reported was a smaller product mix. This is true of some SME's but this is not true of many project based or other make to order, low-volume high-variety and multi-kind manufacturers. An example of this is a precision engineering job shop or a general steel working plant. Their product mix is infinitely variable within the limitations of their staff, machinery, and subcontractor capabilities.

2.3.7 Lean Lacking Contingency for Low-volume High-variety

Lean is commonly misunderstood as being unsuitable for low volume high variety type environments; it is more identified with its roots in mass production. However, it is argued that when you look at the key principles of lean these organisations are already much closer the ideals. The main example of this is the principle of generating one piece flow. Low volume high-variety companies like a typical SME job shop or make to order business are already much closer to this ideal and appreciate quick changes between products (Crute et al., 2003; J. P. Womack & Jones, 2003). The challenge remains to adapt the current thinking to achieve lean production in these enterprises (Crute et al., 2003; Balle, 2011; J. P. Womack & Jones, 2003).

2.3.8 Example of Lack of Contingency: Takt Time

Takt time is one example of an aspect or tool of lean that is difficult to implement in a low-volume high-variety SME. Takt is derived from the German Taktzeit and equates to a standard cycle time, setting the pace for industrial manufacturing lines or systems. For example, all individual processes in a chain of processes operate on the same Takt cycle. This is complicated in high-variety low volume manufacture because of the dissimilar cycle times. During a NZTE lean seminar this researcher was told that takt time was not for those with a low ratio of material costs to labour cost i.e. like low volume high-variety. That sat well with the attendees at the time because it plain and simple made life easier and saved some mental exercises. Put another way the business's *thinking* wasn't broad enough to begin to embrace the concept. But Takt time with level scheduling is mentioned as a core component of TPS and lean practice (Balle, 2011; Ohno, 1988; Shingo, 1989) so can it be ignored? Michael Bale on the topic said that *"There is no lean thinking without takt time thinking"* and pointed to the need for working at establishing takt and level scheduling for your particular environment.

> *"Companies that argue that their business has too little volume, with too much volatility, and too high a mix to apply takt time thinking have gotten hold of the wrong end of the stick. The point of takt time thinking is to shine a new light on your operations, regardless of how variable it is, and to see how rationally you can use your resources. Whatever your product mix and volume variation, how hard can it be to average daily demand over one month, and to divide open time by this number in order to compute a takt? Anyone can do this. Now, the real question is: how can I deliver the exact product customers want 1x1 in sequence, precisely at that takt?"*
>
> (Balle, 2011)

The Takt becomes like the heart-beat or pulse for an operations flow and thus powerful if it can be achieved. A simplistic example of Takt in an SME is applied in preparing quotations. With quote management in one business, the business later referred to as (Company B), it was discovered that the firm on average does 60 quotes in a four week month. The quotes are differing sizes however if every workday of the month (20 days) the estimating function prepares three quotations per day then the months quoting is kept up to date. An extension of the system is that the documents for quotation are arranged in priority order and displayed such that the Managing Director can see if the QS is on target and supports when deadlines are tight and extra capacity is required. Here we see the critical concept of Takt adapted to high-variety low-volume manufacture.

2.3.9 Is Lean Really Universal?

The universality of lean and the claims for this by its proponents, specifically Womack has been challenged. Cooney (2002) criticised these claims. But the report suggested that lean practice was contingent on just-in-time, a tool of lean. This is like mistaking kanban as the system when it is just a tool (Shingo, 1989, p. 67). It is argued (or obvious) that just-in-time (JIT) as a tool is dominant, but is just a tool nonetheless, and should not be confused with the principle. Because of this, it is better to emphasise the elimination of waste and respect for humans as the overriding principles of lean. These are supported by the principles of pull and flow to perfection which is a component of but not limited to JIT manufacture. JIT as its contemporary understood, is a method that should be applied when practicable, when it is the next step towards perfection.

2.3.10 Answer To Critics: Lean Is On A Journey

Critiques like the above have some validity but only in their specific context; that is the time they were encountered, the specific context in which observations were made, or being based on a different understanding of what lean is. Accepting these critiques as being insurmountable would neglect the growing number of successful implementations of lean in a wide variety of fields (Crute et al., 2003; Hines et al., 2008; J. P. Womack & Jones, 2003). Further, it neglects that lean has been and still is on a journey, i.e. it continues to develop. Lean has progressed from a stage of prescription (tools and technique's typically prescribed by consultants) to a deeper stage of understanding specific contexts and needs (Hines et al., 2004).

<u>Framing Lean in the Organisational Development Literature</u>

Lean implementation is not just "doing lean" but an organisational change to a lean learning organisation.

2.4 Organisational Change for Lean Implementation

Although lean management is becoming the standard for systematic productivity improvement, when lean is adopted in traditional organisations it requires a widespread organisational change. Due to the neglect of proper change management, many businesses fail to sustain the necessary lean practices, let alone achieve continuous improvement. Although lean has proven to be customisable to many different business types (J. P. Womack & Jones, 1996; Hines et al., 2008) these issues still remain. Lean failure and rates of failure are somewhat difficult to define, i.e. both defining success as a state and also because with time and persistence some weak cases ultimately prove successful. However the majority of lean implementations are said to fail to sustain. Literature reports 60% to 90% failure rates for improvement programmes (Goodyer et al., 2011; D. Shin, Kalinowski, & Abou El-Enein, 1998). The reported high failure rate of lean implementation is consistent with the high failure of organisational change in general (Kotter, 1995); which is said to be as high as 80% (Burnes, 2005). Many lean implementations are said to fail when practitioners focus on the tools or methods of lean neglecting the strategic thinking with its *human* aspects. These human or cultural aspects are seen as crucial to sustainability but harder to grasp and not apparent or visibly physical when touring a lean business. The misguided focus and resultant failure of implementations has brought lean under criticism and can be a barrier future implementation. These matters are confirmed in various works (Bordia, Restubog, Jimmieson, & Irmer, 2011; Hines et al., 2008, 2004; Liker, 2004, pp. 87, 111; Schmidt, 2011; J. P. Womack, 2007)

This work proposed that for sustained success there is the need for practitioners to gain a thorough understanding of lean through much study and/or experience. Contextual knowledge on how to implement lean for sustainability does exist (e.g. J. P. Womack & Jones, 1996; Hines et al., 2008; Liker, 2004). However further research is needed including outputs that simplify the process for practitioners. Defining how practitioners can gain the benefits of lean addresses the critiques on lean, i.e. showing how to have a successful implementation.

The large numbers of failed or struggling instances necessitate research with emphasis in the area of organisational change. To this end, the review addresses the intersection between organisational change and lean implementation. The literature on organisational change is extensive and the review intentionally avoided many of the exuberant theories, conjecture, and hearsay available in the management practitioner literature. Research targeted literature more pertinent to the lean implementation and organisational change intersection.

2.4.1 History of Poorly Connected Opinions

The review uncovered a plethora of sources on organisational development, change management, and in a broader context systems science. This uncovered concerns of the legitimacy of the body of knowledge, implicated that change approaches did not link well together, did not show a clear causality in factors, and that traditional models were largely *management-centric* and are not satisfactory with the result being a failure to sustain change (Burnes, 2005). Finally, the gap between the science and practice of organisational change was said to be the “single biggest impediment in effective change management” (Pettigrew, Woodman, & Cameron, 2001, p. 709).

Organisational development research is pressing forward but has a past of alleged illegitimacy that overshadows it. Historically the literature has undergone much scrutiny for its conjectural nature with research lacking legitimacy and rigour. Hence, in the 1980’s proponents called for advances in sound research (see Sashkin & Burke, 1987). In the 1990’s the research arguably got richer and more descriptive but still was questioned as a *“cumulative and falsifiable body of knowledge”* growing from “*repeated theoretical propositions”* and “*statements quoted with reverence but not refinement”* (K.E. Weick & Quinn, 1999). The literature is considered *“large and fragmented”* having inadequate emphasis on the sustainability of change (Buchanan et al., 2005). However, although the conjecture does need careful handling, there is also sound research that can be found (e.g. Bordia et al., 2011). It is noted that sound research from other fields (e.g. studies of behaviour) can also be used in support of understanding change (as in Heath & Heath, 2010). There is no doubt that the sea of opinions makes it difficult for a practitioner to know where to start. However, attempts have been made to simplify key aspects of change into easy to follow stage models and frameworks (e.g. Kotter, 1995; Heath & Heath, 2010).

2.4.2 The Change Body of Knowledge

The organisational change body of knowledge developed specifically in the last 60 years (Oreg, Vakola, & Armenakis, 2011; Sashkin & Burke, 1987). Early work is exhibited in the late 1940's (Lewin, 1947), and particular thought leadership in the 70's (e.g. Ackoff, 1972). However the body of knowledge had particularly growth through the 1980's (e.g. Ackerman, 1986; Ackoff, 1981; Sashkin & Burke, 1987) and 1990's (e.g. C. Hendry, 1996; Judson, 1991; Kotter, 1995, 1998; Orton & Weick, 1990; K.E. Weick & Quinn, 1999) into this millennium (e.g. Ackoff, 2003; Anderson & Ackerman-Anderson, 2010, 2001; Heath & Heath, 2010; Kotter & Rathgeber, 2006; Kotter, 1995, 2006; Macrì, Tagliaventi, & Bertolotti, 2002; Pettigrew et al., 2001; Plowman et al., 2007; Porter, 2006; Tsoukas & Chia, 2002). This is just a selection of the work, more is evident from others literature reviews (see reviews by Armenakis & Bedeian, 1999; Becker, 2004; Buchanan et al., 2005; Oreg et al., 2011; Sashkin & Burke, 1987; Üsdiken, Kipping, & Engwall, 2011).

Kurt Lewin was an early and key contributor to change management. After World War II, Lewin (1947) developed a staged process change model that has dominated practice (Burnes, 2005; C. Hendry, 1996) . This was supported by his Force Field Analysis[30] (Lewin, 1947). Although criticised for missing dynamic aspects of change and the fluidity of an organisation (Burnes, 2005; ref. Kanter, Stein, & Jick, 1992), Lewin's thought process and development of this category of thinking are commendable. Mentions include his discussion of the positive influence of group decisions on change (freezing the change) and defining between the correlation and causality of change factors e.g. a decision to buy milk (following education on benefits) may not be the cause for the successful change of habit, however the action that followed the decision may be e.g. placing a standard order for milk (Lewin, 1947).

Planned & Episodic Change

There are two main types of change, planned and episodic. Planned change is episodic as opposed to continuous change which is emergent. Lean is a system in the realm of continuous improvement but continuous change needs further definition. It is also beneficial to define lean implementation from the view of organisational development.

[30] Force Field Analysis brings social science closer to physical science by analysing the factors or "forces" that influence a situation e.g. on a person in the process of change.

Planned, episodic, and synoptic change will be considered synonymous for this work. This type of change is associated with stage models where change has discrete stages. Kurt Lewin's (1947) stage model of change (unfreeze, transition, freeze) is the classic in this field of organisational development (Burnes, 2005). Figure 9 shows this classic but arguably unsuccessful change management model. Once the change is identified, the current state is unfrozen and the change is driven from the top-down. After this, efforts are made to sustain or freeze the change. This may be done by policy. (Lewin, 1947; Burnes, 2005)

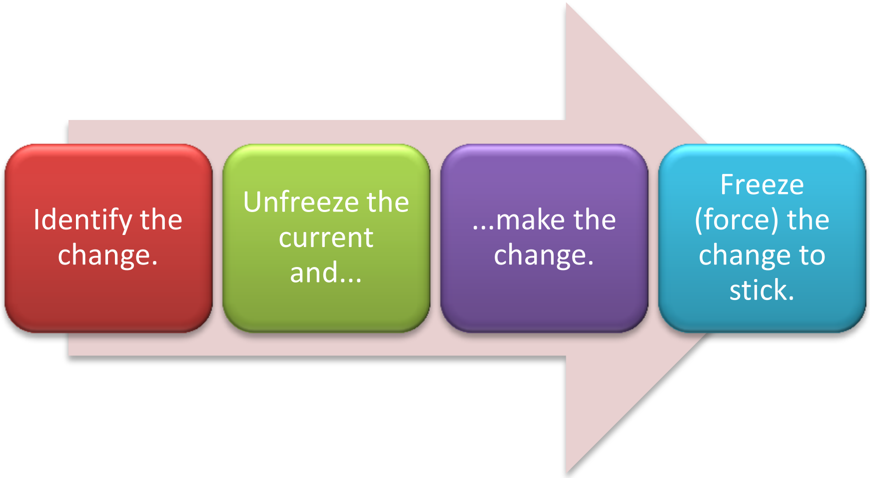

Figure 9 The classic change management model originating from Lewin (1947). The change is identified and driven from the top then efforts are made to freeze the change e.g. by policy. (Image: A. Pearce)

A planned change is episodic because it involves discrete events in time planned out and then implemented. This traditional method tends to be management centric and are criticised by the continuous and emergent change proponents (Burnes, 2005; Tsoukas & Chia, 2002; K.E. Weick & Quinn, 1999). The top-down approach is wrought with issues of resistance and lack of engagement and the classic "Not Invented Here" (NIH) staff response (Heath & Heath, 2010). In the planned approach top management can wrongly assume that change is *"something someone with authority"*, a position, *"does to someone who does not"* have authority (K.E. Weick & Quinn, 1999). One problem is managers (or rather human beings in general) have a high view of themselves and their opinion and neglect that in reality *"managers are not omniscient, strategy setting can be misguided, leadership can be perverted"* and *"resistance to change can sometimes be appropriate"* (Pons, 2010b). Not only is the planned approach wrought with sustainability issues it is also slow to adapt, favouring stability over on-going change.

Continuous & Emergent Change

Continuous and emergent change theories developed as the world situation changed. From the 1950's to the 1980's the planned approach to change was prevailing. Then in the 1980's, in order to remain competitive in the fast moving market place, the world realised[31] the need for more rapid change (Burnes, 2005). The

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[31] This realisation appears to line up with the development and assimilation of the culture-excellent Japanese manufacture in the West.

traditional planned approach is one that prefers stability, where change is only an epiphenomenon and not endogenous (Tsoukas & Chia, 2002). This kind of episodic change involves stages of equilibrium that need to be broken to transition to a new equilibrium (K.E. Weick & Quinn, 1999). But in order to have continuous innovation, emergent change from within the organisation is required. This is the dynamic change needed for survival and prosperity in today's competitive markets (Burnes, 2005). Modern organisations need to be flexible "organic" and able to change quickly. An example of building in flexibility in lean is the use of teams that are self-managing (Liker, 2004).

Continuous change proponents take the view that change is, and should be, on-going within an organisation. Change in organisations does not need to be planned and discrete, but can emerge continuously. In fact, change is occurring in organisations all the time (K.E. Weick & Quinn, 1999) emerging to various degrees and from various levels (Pons, 2010b). True emergent change would be change occurring continuously from all levels as opposed to top-down planned change. In these situations, the speed at which change can take place is much greater (Burnes, 2005). However, small isolated changes may just occur in a wild fashion disconnected from the wider purpose of an organisation. Such change will be difficult for others to accept (K.E. Weick & Quinn, 1999). But, when aligned with the purpose of the organisation, small continuous adjustment can accumulate for substantial positive change. When the small isolated changes are added together, the accumulated results of the seemingly insignificant changes are significant and powerful.

Emergent change is dynamic, continuous, and on-going whereas the episodic concept is a matter of replacing the old with the new. The replacement thought restricts to either-or thinking (K.E. Weick & Quinn, 1999). It involves a significant change from one state to another overcoming existent inertia along the way. Üsdiken (2011) comments *"the history of an organization is considered as one of the internal constraints limiting adaption capabilities".* A planned or episodic change is only contemplated as adoption lags and the need to change is noticed (K.E. Weick & Quinn, 1999). Adoption lags when the emergent change is not significant enough, i.e. it has been limited by the internal inertia or constraints. As Weick et al. (1999) state:

> *Episodic change is driven by inertia and the inability of organizations to keep up, while continuous change is driven by alertness and the inability of organizations to remain stable.*

Continuous change is about a continuum of adaption rather than discrete events of planned change. To achieve this "evolving" change the authority to change a thing is distributed to those with the most information regarding that thing e.g. a production worker. Flat flexible structures that allow for this type of *culture excellence* are called for. Such organisations operate as complex non-linear systems with unpredictable change outcomes but are governed by simple rules for allowing operation at the *edge of chaos* i.e. at the condition for maximum amount of allowable and on-going change (Burnes, 2005). Complexity theories for emergent change are versus stability and challenge linearity with system components constantly interacting through a network of feedback loops (Plowman et al., 2007). This is like the example of an acrobat on the tight rope:

"…We say the acrobat on the high wire maintains her stability. However, she does so by continuously correcting her imbalances."

(Sashkin & Burke, 1987, ref. Bateson, 1979)

Stability without change could be seen as beneficial and desirable in some bureaucratic organisations (Liker, 2004, p. 144) however there is a clear call for high levels of change in order to remain competitive. Plowman et al. (2007) suggests that novelty can only emerge from instability.

For environments of change to come forth organisational cultures need to be reviewed and old inertias need to be smashed. Structure, previous success, management tenure, and identity maintenance are among such inertias restraining episodic change (K.E. Weick & Quinn, 1999). Much more needs to be overcome for to achieve the required levels of emergent change. (Burnes, 2005; Sashkin & Burke, 1987; Tsoukas & Chia, 2002; K.E. Weick & Quinn, 1999)

From this review, it was proposed that lean implementation is best described as a planned change for continuous emergent change, in effect developing a learning organisation.

2.4.3 Organisational Learning and the Learning Organisation

Organisational learning has close ties with continuous improvement (Murray & Chapman, 2003) and has been integrated with the lean literature (Fynes & Ainamo, 1998; Lantelme & Formoso, 2000; Lewis, 2000; MacDuffie & Helper, 1997; Morgan & Liker, 2006). The concept of a learning organisation was publicised in the work of Peter Senge (Senge, 1990). This concept, coming out of organisational learning and related research, has been particularly beneficial in explaining the dynamics and systems of genuine lean continuous improvement, even describing a goal state, i.e. becoming a learning organisation (Dahlgaard & Dahlgaard-Park, 2006; Hines et al., 2008, 2004; G. Lee, Bennett, & Oakes, 2000; Liker, 2004; Ricondo & Viles, 2005) and has been related to sustaining lean in New Zealand (Mohd-Zainal, Goodyer, & Grigg, 2011). Its core concepts allow for useful dialogue, communicating key complexities of lean.

A concise definition of a learning organisation or learning company is given by Pedler in 1989 (Pedler, Boydell, & Burgoyne, 1989), "an organisation which facilitates the learning of all of its members and continuously transforms itself". In short it is an organisation whose learning capabilities have become excellent, but specifically implies management has intervened such that the organisation will continuously learn (Tsang, 1997). Double-loop verses single-loop learning (Argyris, 1977) is a particularly key concept in the learning organisation (Senge, 1990), especially as related to lean (Hines et al., 2008). Single-loop learning implies repeated attempt at the same problems without adjustment. It implies a short term solution for a problem that may arise in the future. Double-loop learning implies a modification that occurs, to change the method and goal or even reject the goal.

The learning organisation is attributed by five characteristics according to Senge (1990): systems thinking, personal mastery (individual commitment to learning), mental models (values, assumptions, boundaries, and norms need to be open to change), shared vision, and team learning.

Although the completeness of Senge's presentation is challenged (Caldwell, 2012; O'Keeffe, 2002), the promoting and facilitating of learning within the organisation, being integrated into the systems of the organisation, even the forcing of learning, was observed in the TPS and seen as key to lean success (Hines et al., 2008; Liker, 2004; Ohno, 1988).

2.4.4 Successful Change is Sustainable Change

From the early stages of change research, sustainability was identified as a key issue (Lewin, 1947) and continues to be (e.g. Buchanan et al., 2005; Heath & Heath, 2010; Kotter, 1995). Lewin (1947) stated:

> *"A change toward a higher level of group performance is frequently short lived; after a 'shot in the arm', group life soon returns to the previous level. This indicates that it does not suffice to define the objective of a planned change in group performance as the reaching of a different level. Permanency of the new level, or permanency for a desired period, should be included in the objective."*

This thought of permanency or sustainability is the test of a successful change and as a concept was pertinent to this work.

2.5 Lean Implementation—An Enterprise Transformation

2.5.1 A Typical Implementation

In Figure 10 is the process of a typical lean implementation (Rivera & Frank Chen, 2007). First, it prescribes value stream mapping (VSM) to define the journey of improvement. Next, there is the organizing of the house. The organizing or cleaning of the house uses implementation of flexible work systems but primarily 5S (sorting, straightening, systematic cleaning, standardizing, and sustaining). 5S is a typical first step in implementing lean. It is easy to understand that organising your workplace can improve efficiency. Following this, specific tools are provided to improve the processes. These tools are typically standard work, SMED, TPM and Jidoka as discussed elsewhere in this document. Finally, the implementation reaches full JIT pull systems with heijunka (level scheduling).

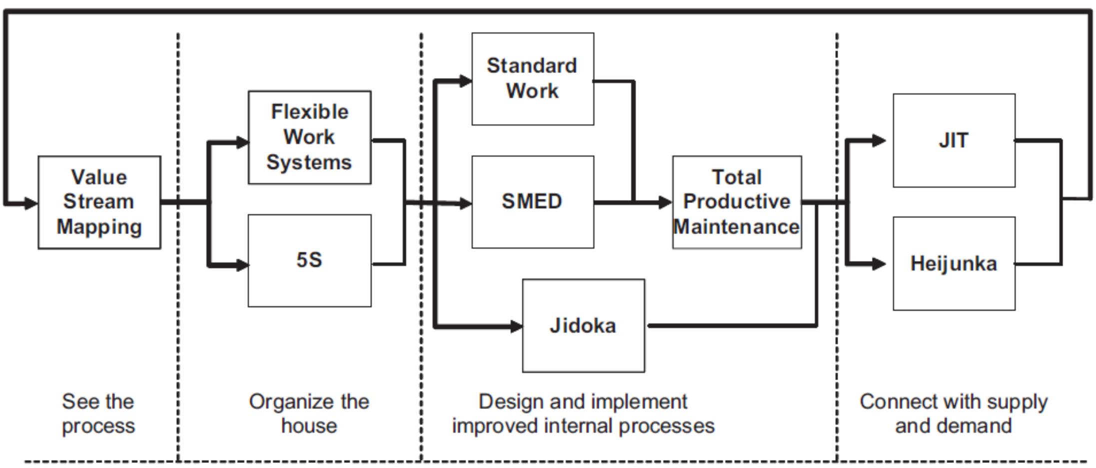

Figure 10 A typical process for lean implementation as given by Rivera and Frank Chen (2007). (Image reproduced with permission)

Given these readily available tools and an understandable process, a business which is supported by a consultant can readily embark on a lean journey. The unfortunate thing is the over focus on these tools. Further discussion addresses an erroneous seeking for quick fix tools and methods as the antidote to increasing productivity and addressing other performance issues. There is a neglect of the underlying principles of lean and developing proper strategic perspective and a culture of sustainability. The inevitable result is implementation failures that become negative experiences and hinder future attempts at continuous improvement. This also would hinder seeking further knowledge in the field as an attitude of "we've heard this before" passes lean off as another fading fad. The resistance that results from unsatisfying experiences was confirmed by the organisational development literature (Bordia et al., 2011) along with the high failure rate for change (Burnes, 2005; Kotter, 1995). The use of consultants is also addressed. Often consultants are used to achieve a temporary success by applying specific tools to some processes but unfortunately, overall effectiveness is limited. This failure is considered a lack of a business's actual understanding and assimilation of what lean is about and coinciding failure to become a learning organisation. (Hines et al., 2004; Dahlgaard & Dahlgaard-Park, 2006; Liker, 2004)

2.5.2 Lean Misunderstood as a Tool Kit

The contemporary research states, for lean to truly have impact there is a need of an enterprise wide understanding that is embedded in the company culture starting with leadership to build a learning organisation (J. P. Womack & Jones, 2003; T. A. Boyle, Scherrer-Rathje, & Stuart, 2011; Hines et al., 2008; Liker, 2004). The extent to which lean thinking in an organisation reaches this level of understanding, effecting the internal culture and eventually external supplier cultures indicates the extent to which the benefits of lean will be seen in that organisation. As Boyle et al. (2011) comments:

> *"In order to truly understand the extent of lean adoption, it is critical to not only capture the piecemeal usage of individual lean techniques (e.g. single-minute exchange die/setup time reduction, 5S), but also the existence of the higher level strategic orientation and philosophy that represents lean thinking."*

Schmidt (2011)[32] further comments on the misinterpretation of lean developments in 1991, and confirms this is very much the case today also.

> *How to proceed was outlined 1991 in [16]: "The key is not to adopt the methods and the systems but to understand their foundations. The next step is to assess which parts can be adopted or adjusted to the circumstances at hand and, most importantly, what could be improved. Extensive English literature on the Toyota production system as well as Japanese production methods has been in*

[32] Here Schmidt quotes a translation into English of his own article: S. Schmidt, "Produktivitätsorientierte Instandhaltung , (TPM) – Ein Weg zur Kostensenkung in der Automobilindustrie," Blick durch die Wirtschaft, Sept. 18, 1991.

circulation for the last ten years. If it required research at MIT to understand the signs of the time, then many companies have misinterpreted the development of an entire decade."

Lean is often misunderstood to be a set of tools alone. The tools are often adopted in part in the name of a lean implementation. However, lean's true benefit is seen when the deeper thinking is applied in order to ensure the following: that value is understood and flows with as little wasteful actions as possible, when the customers pulls it from the system This is what is emphasised in Lean Thinking (J. P. Womack & Jones, 2003).[33] Moreover, this thinking should pervade the whole organisation. Unfortunately, to see, apply, and sustain this is not always straight forward. A process of implementing piecemeal tools and techniques is a lot easier grasp.[34] For instance, it is easy to understand that the housecleaning and organising type of work achieved with the 5S system will benefit a company. It is also relatively easy to plan for and execute such an implementation, and in truth any typical mass production organisation would likely benefit from such implementation (Hines et al., 2008). However, it requires another level of thinking to define value from the customer's perspective and uncover how you can flow value to the customer in "customer size" pieces as they, the customer desires. It is even further difficult to achieve and sustain the internal culture of strategy, leadership, employee behaviour, and employee engagement needed to have an embedded culture of lean continuous improvement at all levels. (J. P. Womack & Jones, 2003; Hines et al., 2008; Crute et al., 2003; T. A. Boyle et al., 2011; J. P. Womack et al., 1990; Balle, 2011; Hallam et al., 2010; Liker, 2004, pp. 87, 111, 175)

To summarise, the relative ease to implement and understand the tools over the higher level strategic and cultural thinking has influenced the approach to lean implementations. With the typical *tool approach* initial benefits are achieved no doubt but sustainability is not, and there is a resultant high failure rate of lean implementations. The literature reveals this further.

2.6 Lean Sustainability Models

2.6.1 Back to Toyota: "Respect for People" for Success and Sustainability

To start, credit is due to the originators of the lean TPS. It is not that Toyota missed it, it appears for decades practitioners have missed what Toyota had really achieved. Lean is for the absolute elimination of waste but

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[33] The strategy for lean implementation described in Lean Thinking (J. P. Womack & Jones, 2003, p. 248) was broad and inclusive. The book was not tool focused in its approach and barely expounded on the myriads of tools available. It focuses on the 5 key principles of defining value, mapping the value stream, developing flow, and pull, unto perfection The text is from the early stages of lean's development but the points for implementation did give factors for organisational change. It mentioned finding a change agent, creating a crisis (the lever for change), creating lean functions, devising policy for the excess staff (increasing sales being the favourable strategy), removing troublesome employees, initiating policy deployment, having lean learning, and stretching towards your supplier and customers. The text also discussed that managers must be coaches and the employees must be proactive as the key to self-sustaining implementation (p. 268). Details regarding the change agent becoming a problem at later stages in an implementation were also discussed. The change agent, necessary to get change started, may need a system builder behind him and eventually may need to withdraw, moving on, and leave a more suited manager to maintain the implementation, i.e. especially as the company shifts from top-down to facilitate bottom-up employee initiation of improvements.

[34] Also the tools are much more visible when one visits an exemplary lean enterprise.

Ohno considered the *respect for humans* principle equally important (Ohno, 1988). Minimising waste should not be the sole target. Waste reduction should be considered as the result and engaging and empowering people are the means to reach the goal. Engagement and empowerment of employees can be considered more important, rendering longer lasting results (Hines et al., 2008, p. 7). As Schmidt (2011) comments:

> *Minimizing waste should be the result not the goal. It is more important to empower all employees to contribute to the accumulation of knowledge at their own work station in order to optimize procedures – otherwise the danger arises that the accumulation of knowledge will be neglected in favour of focusing all efforts on the avoidance of waste. In this case one will never progress beyond the initial success. When "Avoid all forms of waste!" is declared the sole target, many will hesitate to invest in areas, which have a history of underfunding. Typically this affects the local accumulation of knowledge. This situation even affects some of the big corporations, which have a history of lean production, because they failed to realize that.*

This discussion by Schmidt (2011) [35] points out that there are below the surface factors critical to the success of a lean implementation. These factors are not as tangible as lean tools but are critical. Having these factors, e.g. employee engagement and empowerment through the proper guidance and training by committed managers (Balle & Balle, 2009, p. vii), can issue in a culture-excellent learning organisation (Hines et al., 2008; Liker, 2004). Therefore, practitioners are encouraged to avoid being fixated on the methods; there is a philosophy, and there are tools, but they must be appropriately applied (Liker, 2004, p. 111).

2.6.2 Contemporary Lean Sustainability Models

Existing Frameworks for Success and Sustainability

There are existent models of lean implementation but few sufficiently focus on lean success and sustainability (permeability). Lean has this in common also with the change literature. Various sustainability models have been reviewed for SMEs in New Zealand (Goodyer et al., 2011; Murti, 2009; Stamm, 2011). Of the models, many come from or at least are accounted for in Cardiff Universities Lean Enterprise Research Centre (LERC) research (e.g. Found et al., 2006; Hines et al., 2008, 2004) which culminated in the frameworks of Staying Lean (Hines et al., 2008, 2011).

A prominent framework is the Liker (2011; 2004) 4P model. The 4Ps are philosophy, process, people and partners, and problem solving. These are expounded into 14 principles that make up the majority of the popular text The Toyota Way (Liker, 2004). The Toyota Way labours the culture, the processes, and leaders that are needed to develop a learning organisation. The model is good and the text insightful but not as vivid as the Lean Iceberg. The Lean Iceberg (Hines et al., 2008, 2011) is a graphic and telling model clearly pointing to basic causality of implementation failure; practitioners tend to focus on tools and processes rather than taking a

[35] Quotation of German language article by M. Furukawa-Caspary, "Menschen befähigen vs. Verschwendung vermeiden,"Das synchrone Produktions- und Management system – SPS Intensivseminar, Karlsruhe, May 2009.

holistic approach. The relevance of this model to the SMEs in New Zealand has been confirmed (Goodyer et al., 2011). Liker (2004) included a similar but less specific iceberg model in The Toyota Way (p. 298).

2.6.3 The Lean Iceberg Model: A Balanced Approach for Sustainability

The Lean Iceberg Model (Hines et al., 2008, 2011) is an analogy for the two aspects of a lean organisation, the visible and the invisible (Figure 11). The visible aspects are those above the waterline and the invisible aspects are those below the waterline. This is similar to a tree analogy; the roots, which are crucial to the health of a tree, are hidden below the surface. Above the surface, or waterline, are the technology tools & techniques, and processes. The visible aspects are readily understood and are noticed when touring a lean business. As discussed earlier, these above the surface aspects are relatively easy to grasp and implement. The danger is to over focus on the tools and methods of lean and have only a limited appreciation and application of the below the less visible aspects which are crucial for sustainability. These aspects are identified as strategy, alignment to strategy, leadership, employee behaviour, and employee engagement.

Figure 11 The Lean Iceberg Model shows the above the waterline (visible) and below the waterline (invisible) aspects of a lean implementation. Typically the below the waterline aspects are neglected although crucial to sustaining a lean implementation. (Depiction made by Pearce[36] of Hines et al. [2008] Lean Iceberg Model)

Recent research in New Zealand focused on and supported the use of the Hines (2008) Lean Iceberg Model. This was initiated by NZTE and accomplished as the master's research of Murti (Murti, 2009) and presented as conference papers (Goodyer et al., 2011; Grigg, N.P., Goodyer, Murti, & Shekar, 2010). The findings

[36] This illustration, depiction of the Lean Iceberg Model, was made by Bethany Pearce.

concurred with the Lean Iceberg Model by the negative case. The studies showed the New Zealand firms exhibited piecemeal usage of tools to provide quick wins without the necessary strategic focus and leadership with an emphasis on employee behaviour and employee engagement. Such effort led to early wins but not sustained results.

2.6.4 Existing Frameworks for SMEs – Tools focus

Frameworks for implementation in lean SMEs have been developed by others (see Rose, Deros, & Rahman, 2010; Rose, Deros, Rahman, & Nordin, 2011; Thomas, Barton, & Chuke-Okafor, 2008). However, these frameworks tend to a tools focus, e.g. what tools to implement first, without a strong emphasis on sustainability. These frameworks tend toward lean as a project rather than developing organisational culture for excellence. They also tend towards reliance on external support. Indications are reliance on consultants could be particularly dangerous in SMEs. This needed further investigation.

A concurrent work to this, Stamm (2011) proposed a framework for the integration of lean in New Zealand manufacture-to-order SMEs. Stamm's research recognised the specific characteristics of SMEs and New Zealand. Stamm's developed model was more holistic than the other SME studies referenced. However, the framework still gave a lean expert approach to gaining knowledge. Stamm's references indicated blanket training of staff and that training focuses on methodologies. Management knowledge may be equally or more important than specific techniques.

2.6.5 Further Frameworks Needed

It was concluded that firstly, the methods of lean do work however, they need sustainability, and secondly the full benefits of lean have been associated with a culture-excellent learning organisation. Finally, a learning organisation was associated with the *below the waterline aspects of the Lean Iceberg Model*.

The proposal was to further the knowledge on lean success by developing statistical models of causality. The model would include factors from the existing lean body of knowledge, change literature and any additional insights.

2.7 Sustaining Lean—Uncovering Success Factors

2.7.1 Understand Change and the Factors

A detailed understanding of the factors for lean success was needed; this necessitated an exploration of the organisational change literature. In the large part, the factors relate to people and their behaviour as the "struggle" with change. *In essence, the following literature review incorporates the organisation change body of knowledge to expand on and merge with lean sustainability. The key factors for sustaining lean transformation are identified.*

2.7.2 Making Change Stick without Bureaucratic Force:

An organisation undergoes a lot of change when implementing lean. For example, take going from a batch and queue model of manufacture to a JIT one–piece flow scenario. The systems change, layouts change, and technology may change; the way employees work change, their positions change, and departments may be disestablished altogether. If quality control shifts to the source, and less emphasis is placed on the QC department. Expediters, the old heroes, lose their position as lead times naturally drop. Workers also lose any specialist identity when flexibility is required. These kinds of changes are difficult for people to manage (Delbridge, 1998; J. P. Womack & Jones, 1996) and the result appears like resistance. The traditional treatment for resistance is bureaucratic force, but if the goal is continuous improvement through emergent change, the culture needs to be developed rather than crushed. Culture is cash (Spence, 2012), people need to be lead and not just rearranged and re-programmed like robots on a production line (Pons, 2010b).

A Vivid Analogy for the Challenge of Change:

When considering factors of organisational change a vivid analogy, for the individuals undergoing change is an elephant and its rider on a journey (Heath & Heath, 2010; ref. Haidt, 2005). Everyone has a rational side that can be directed to change and in many cases wants to change but may lack the self-control or energy to make the change. This rational side is the rider who is trying to direct the large elephant, the emotional side. The emotional side is hard to control unless it is strongly captured and motivated. This elephant exhibits itself in many New Year's resolutions regarding diet and exercise. These resolutions, like other change efforts, are agreed on in the mind but regularly fail. Logically it is difficult for the rational mind – the rider - to keep the emotion - the large elephant - under control. In change, the mind needs help by giving it clear direction and the emotion needs motivation by touching the feeling for change. Additionally there is the path or the journey of change. The path needs to be clear to make it easier for the elephant. The path represents the situation or environment of change. To have success, change is supported by the rider (rational mind) being clearly directed, the elephant (emotion) being motivated and the path (the environment) being cleared of obstacles.

2.7.3 Behaviour or Reactions to Change

> *At the heart of events, however, and a main determinant of the extent to which any change can succeed, is how change recipients react to organizational change.*
>
> (Oreg et al., 2011)

Reactions to change have been characterised. First is affective reactions which negatively are stress, fatigue, and negative emotions; and positively are pleasantness, satisfaction and commitment. Second is cognitive reactions, e.g. sensemaking, decision satisfaction, commitment, support for strategy, openness to change, and perceived fairness. Third is behavioural reactions e.g. active involvement or withdrawal, undermining or opposing, and supporting the change (Oreg et al., 2011). For sustainability the negative reactions or resistance to change needs to minimised. However, the literature suggests *resistance may be a matter of perception and not a problem of difficult people.*

2.7.4 Resistance to Change: Is It a People Problem Or Something Else?

"Change begins at the level of individual decisions and behaviours, but that's a hard place to start because that is where the friction is."

Heath (2010), p. 56

When a genuine change is instigated, the basics of why it does not stick could be considered as a sum of the individuals' resistance. When the shape of a rubber ball is changed, the elastic forces resist and it soon springs back to its original shape (or very close to that shape). In order to understand change then it is helpful to understand where the force for preservation originates from. From the review, three key sources of resistance have been identified, i.e. a person's lack of understanding, a person's lack of self-control, and warranted resistance.

A Lack of Understanding

Resistance to a proposed change by an individual or group may come because of a lack of understanding (a sensemaking process). The outcomes of a change may be positive for the party concerned but because of misunderstandings, they resist. Lean is no stranger to this, because of misunderstanding lean implementation has been received with negative connotations being referred to as "mean" engineering (J. P. Womack & Jones, 1996; cf. Delbridge, 1998). Also, because previous change efforts may have issued in bad experiences, the intentions of new ones are undermined (Bordia et al., 2011). These kinds of life experiences shape responses to change (Ackerman, 1986). Employee resistance does not necessarily mean the intended change is wrong, but what is perceived by the participants concerns them. *In fact, what appears like resistance may just be a lack of clarity* (Heath & Heath, 2010, p. 15). Employees internally ask *"What does this change mean to me?"* (Ackerman, 1986). Being unclear of how a change will benefit the organisation, and particularly the person themselves, understandably causes a reaction of resistance. Hence, an error in understanding and lack of clear vision (Kotter, 1995) regarding is a positive change may cause negativity, resistance, and ultimately the failure to sustain the change.

A Lack of Self-Control

A lack of self-control, capability, or tolerance for change may also be seen as resistance. Some literature points to laziness, ignorance, and force of habit as factors. But this is a management-centric view (Pons, 2010b) that commits the *Fundamental Attribution Error* (L. Ross, 1977; Heath & Heath, 2010, p. 180). Fundamental Attribution Error is committed when poor (or for that matter good) behaviour is attributed as a trait that cannot be adjusted by the likes of a new situation or motivation. That of course is incorrect and appropriate caution is needed to avoid such error. As Heath & Heath (2010, p. 220) state:

> *"A good change leader never thinks. 'Why are these people acting so badly? They must be bad people.' A change leader thinks, 'How can I set up a situation that brings out the good in these people?'"*

This is in line with the lean TPS respect for humans principle (Ohno, 1988). Change is stressful and it takes a lot of self-control to form required new habits and face new situation. Unfortunately the difficult of change is under estimated (Kotter, 1995) and the skills needed for coping with transition are forgotten (Ackerman, 1986). So, rather than seeing resistance as the manifestation of a “bad” employee, there may just be a lack of self-control; an inability or low tolerance for handling the change (Heath & Heath, 2010; Kotter & Schlesinger, 1979).

Resistance May Be Warranted

The third point here is that resistance may be warranted. In truth *“managers are not omniscient, strategy-setting can be misguided, leadership can be perverted”* and sometimes resistance to change is actually warranted (Pons, 2010b). It is known that the *“good sound judgement”* and *“common sense”* of management is regularly erred (Ackoff, 1981, p. 21). This is true of the assumption that change is something managers (persons with authority) do to staff, those without authority (K.E. Weick & Quinn, 1999). The internal constraints of the organisation limit its adaptive capabilities (Üsdiken et al., 2011) and only management-centric approaches to change prevail. In this way, *lean change* is sometimes pushed onto staff, rather than pulled[37] by them (J. P. Womack & Jones, 2003, p. 268). This means that the employees with access to the most information regarding there area (Burnes, 2005), are not included in decisions regarding it. Thus, an insightful piece of information can be missed and so the resultant resistance is not only valid, but should be paid good attention to.

Additional Reasons for Resistance

There are other common reasons for resistance to change. These include: employees feeling a lack of ownership and resisting anything *not invented here* (NIH) (Heath & Heath, 2010; Hines et al., 2008); staff wondering about the benefit to themselves (“What’s in it for me?”); personal struggles between new and old identity (Heath & Heath, 2010); setting of unrealistic goals; detection of management motives (Pons, 2010b); management not committed to walking the talk (Kotter, 1995).

Whether to fail to change is deemed a resistance, or just an inability to maintain the new desired shape, is a matter of semantics. However, what is clear is that there are hurdles to change that need overcoming and negotiating.

2.7.5 Innumerable Factors

There are a near endless number of factors required to truly understand change. These factors may come from the change recipient characteristics, the internal and external organisational context, the change process, the perceived benefit or harm, and the content. In this review the key factors, those pertinent to sustaining lean organisational are extracted and presented.

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[37] This statement points to lean pull systems. In pull systems goods and services are only provided at the customers’ requirements. That is when the customer “pulls it” from the system. In the same way change should be instigated when the employees (the ‘customer’) require it.

Others have used a questionable approach, reviewing the lean literature to identify the importance of various aspects of lean implementation (see Anvari, Norzima, Rosnah, Hojjati, & Ismail, 2010; 2011). To avoid bias, the researcher prefers investigating reliable and well tested research cases as opposed to the majority of cases (see Selecting Factors, p. 79).

2.8 Leadership—Factors for Overcoming the Hurdles to Change in Lean Implementation

2.8.1 Leaders Leading Change - Not Merely Managing It

A target of this work is organisation leaders, supporting the leaders of SMEs with implementing lean. In general any member of an organisation can cause change if they are given time and persistence, whether or not they are in a position of authority (Heath & Heath, 2010, p. 258). However, even change from lower levels of hierarchy is still a matter of leadership. This is why the terminology *change leader* is preferred to *change manager*. Managed change is associated with the planned, episodic top-down changes where bureaucratic forces play a large part in controlling change and resistance (see Planned & Episodic Change, p. 39), but business transformations needs to be lead, rather than managed. Unfortunately, there are many mangers and few leaders (Kotter, 1995). Kotter (2011) discusses the difference:

> *"Change management, which is the term most everyone uses, refers to a set of basic tools or structures intended to keep any change effort under control. The goal is often to minimize the distractions and impacts of the change. Change leadership, on the other hand, concerns the driving forces, visions and processes that fuel large-scale transformation.*
>
> *…change leadership is just fundamentally different—it's an engine. It's more about urgency. It's more about masses of people who want to make something happen. It's more about big visions. It's more about empowering lots and lots of people. Change leadership has the potential to get things a little bit out of control. You don't have the same degree of making sure that everything happens in a way you want at a time you want when you have the 1,000 horsepower engine. What you want to do, of course, is have a highly skilled driver and a heck of a car, which will make sure your risks are minimum. But it is fundamentally different.*
>
> *The world, as we all know right now, talks about, thinks about, and does change management. The world, as we all know, doesn't do much change leadership, since change leadership is associated with the bigger leaps that we have to make, associated with windows of opportunity that are coming at us faster, staying open less time, bigger hazards and bullets coming at us faster, so you really have to make a larger leap at a faster speed. Change leadership is going to be the big challenge in the future, and the fact that almost nobody is very good at it is—well, it's obviously a big deal.*

The change leaders are the coaches; these coaches facilitate the transformational change.

2.8.2 Providing Clear Direction and the Critical Steps

In making change, leadership should provide clear direction as well as the critical steps of change. This helps employees in understanding the change and their role. To lead a substantial changes requires specific skills. It enters the participants into a realm of ambiguity and has a goal that may be a moving target (Ackerman, 1986). If the participants do not have the ability to change, the result is resistance with a lack of self-control. Lean implementation is not entirely straight forward, and the real leadership learning is through experience, the *"doing"* (Balle & Balle, 2009, p. vii) out of the classroom (Ackerman, 1986).

Although the path is not clear for leaders, it is still important that employees have the desired behaviours made clear to them. This is scripting the critical moves and specific behaviours required for progress. Having clear direction (Kotter, 1995) saves on the self-control a person needs to exert (Heath & Heath, 2010). In providing clear direction, it is beneficial to look for *bright spots*, things that have or are going well. These can then be replicated or highlighted. Looking for sign of bright spots can help from being distracted in analysis, trying to find big solutions to big problems as opposed to the little things that are already working (Heath & Heath, 2010, pp. 27, 33). Additionally, employees need to be brought to *"understand and accept"* the need or the drivers for change (Ackerman, 1986). A simple and clear vision needs to be vividly communicated (Ackerman, 1986; Kotter, 1995). The vision can be laddered down to the specific behaviours required (Heath & Heath, 2010, p. 63; Hines et al., 2008, p. 25). Leaders need to find ways to provide staff with vision and clear direction for the critical moves of change.

2.8.3 Providing Motivation towards the Goal

Find the Feeling

Overcoming the weakness of staff to make a change requires their motivation towards the goal. This necessitates finding the feeling, the attraction for emotional engagement. It is ideal that change is pulled[37] from the staff rather than pushed on them (J. P. Womack & Jones, 2003, p. 268). Unfortunately, when change is difficult, managers tend to respond with bureaucratic force and overlook attraction and its power (K.E. Weick & Quinn, 1999). Other ways of motivating employees are needed. Research indicates that merely understanding the need for change is not enough (Kotter & Cohen, 2002, p. x) and highly successful change mostly happens "*by speaking to people's feelings"* and "*feelings then alter behaviour sufficiently to overcome all the many barriers to sensible large-scale change"* (Kotter & Cohen, 2002, pp. x, 12).

Heath (2010, p. 107) provides the following analogy:

> *"Trying to fight inertia and indifference with analytical arguments is like tossing a fire extinguisher to someone who's drowning. The solution doesn't match the problem."*

So imparting understanding alone is not enough. But managers instinctively will reach for analysis and present the "convincing" figures – e.g. financial ratios. This is relying on "Analyze-Think-Change" which may work for small adjustments but where the future is unclear, further motivation is required. Leader's need to find the feeling, grab the emotion, find something that hits home (e.g. visual). This is See-Feel-Change. (Kotter & Cohen, 2002, p. 12; Heath & Heath, 2010, pp. 106–107; Kotter & Rathgeber, 2006)

Creating Urgency and Addressing Fear

Some call for creating a crisis and even a burning platform for change. Kotter (1995) labels failure in creating urgency as Error #1 in change leadership. Kotter suggest fifty percent of the change efforts he viewed failed for lack of urgency; he discussed a case of engineering a financial crisis to drive change. Toyota's discovery of lean manufacturing issued from the need to compete in the automobile market. The following assimilation of lean into the West issued from its own crisis, the lost market share and need to catch up with Toyota (see p. 21). Additionally, It is said of Toyota that "It aims for stability AND fosters a mindset of paranoia" (Osono et al., 2008). The mindset of paranoia is to drive innovation and improvement.

There is caution regarding taking a *"burning platform approach"* due to the specific emotions it produces (Heath & Heath, 2010, p. 118). This approach is references the Piper Alpha oil platform where disaster left you with the choice: "fry or jump" (William E. Smith & Helen Gibson, 1988). Some change proponents promote creating a dire situation to instigate a kind of fear. This fear forces people to change from what they previously saw as successful (Garvin & Roberto, 2005). However, Heath (2010, p. 118) takes the view of Fredrickson (1998). Fredrickson (1998) discussed the desirable positive emotions in complex change situations. Whereas "Fear and anger and disgust" give a sharp focus like "putting on blinders" positive emotions are more likely to broaden and build. An example of positive emotions is the *interest* to get involved and learn or tackle new things and the *pride* of achieved goals to motivate for bigger goals. *"Most of the big problems we encounter in organizations or society are ambiguous and evolving. They don't look like burning bridges"* e.g. with a simple action – jump or be burned. *"To solve bigger, more ambiguous problems, we need to encourage open minds, creativity, and hope…instil hope and optimism and excitement"* (Heath & Heath, 2010, pp. 122–123). This agrees with Deming and his 8th principle, *"Drive out fear, so that everyone may work effectively for the company"* (Deming, 1986, Ch. 2; Deming Institute, 2012). Thus, the better approach is create an urgency, need and desire to change whilst avoiding fear as the motive but stimulating positive emotions.

Dealing with Identity and Defeatism

An effective way of engaging staff is by adjusting their identity. Your identity, how see yourself, very much depicts how you behave. With this view, reaching for incentives for behaviour change can be clumsy i.e. behaviour is related to identity. This is why Heath (2010) charges to explore how to "make your change a matter of identity rather than a matter of consequences?" because "any change effort that violates someone's identity is likely doomed to failure" (Heath & Heath, 2010, p. 154).

The matter of identity leads or involves the matter of the growth mindset (Heath & Heath, 2010, pp. 162–163; ref. Dweck, 2006). This is particularly important for a culture of emergent change and the identity and learning process involved with lean. For example, a staff member needs a change in identity from say machine operator, line worker or office clerk–to–problem solver, inventor and improvement specialist.

However, the new identity needs to be safeguarded with the growth mind-set. It involves the expectation of failure en-route to the goal. In change, a *"buffer against defeatism"* (Heath & Heath, 2010, p. 169) is needed. The growth mindset says: improvement or growth is possible but growth comes with some struggle (Heath & Heath, 2010, p. 175). The growth mindset in change recognises *"Everything can look like a failure in the middle"* (Kanter, 1999). It involves someone's view about themselves, their view about others and their ability to grow and overcome obstacles (Heath & Heath, 2010, p. 163). This is as opposed to making the Fundamental Attribution Error mentioned earlier. Toyota's approach exhibits the growth mindset towards staff. In a sense it has to, because of the implications of lifetime employment in Japan. The Toyota way involves growing their people to produce a learning organisation (Liker, 2004).

Downsizing the hurdles: making the change easier

Small challenges of change can seem very large in people's eyes, and they need the confidence that they can overcome them. The people themselves can be grown, alternatively, the change can be made smaller. Leaders can *engineer success* by *engineering hope* through setting small but visible goals that can be achieved (Heath & Heath, 2010, p. 144). These achieved goals become small wins. According to Karl Weick (1984), "*A small win reduces importance ('this is no big deal'), reduces demands ('that's all that needs to be done'), and raises perceived skill levels ('I can do at least that')".*

With lean, some have the thought that the first change needs to be sufficiently large affecting a critical operation and grabbing attention of all. However, the ultimate goal is to grow a culture and accumulate experience for on-going improvement. A quick-fix approach to prove a methodology may show the benefits of lean but doesn't necessarily aid in showing others how they can overcome their own obstacles. Rearranging a factory may show management commitment and produce great results, but those results may even be better if employees have already been engaged with small wins, and if they have developed the growth mindset for themselves. A small start may be better for the long term success through sustainability (Hines et al., 2008). Again from Weick (1984):

> *A small win is a concrete, complete, implemented outcome of moderate importance. …[And is] more structurally sound than a large win because small wins are stable building blocks."*

Small wins may seem trivial to the big picture, but are relatively easy to achieve and build hope and confidence to continue on the journey, one small goal at a time (Heath & Heath, 2010, p. 147). In this way, change may feel slow (Schroeder, 2012), but it is possible to achieve transformational change in a slow steady accumulation as people's behaviours, habits, and views adjust. It may be slow, but this is a real change not just a temporary adjustment of practice.

Small Wins Versus a Crisis

This discussion of small wins points to an additional issue with using a crisis. Using small wins addresses the individual's perception and uncertainty of their capability. Thus, regarding creating a crisis, Weick's (1984) contribution is considered:

> *"When people scale up the gravity of social problems, they raise at least the importance of the issue and the magnitude of the demand. The crucial question then becomes:* ***What happens to the third variable of perceived capability to cope with demands****?" [Emphasis added]*

By creating a crisis, the need for change is emphasised, but the challenge could also be scaled up. If the urgency is scaled up, the perception of inability, the hurdle to change might also scale up. There is a balance between creating urgency and paralysing participants. This can be achieved by communicating how the problems can be overcome in small achievable goals.

2.8.4 Embedding Change, Keeping the Journey Going

Lean, as a transformational change is a journey that needs to be maintained. The initial planned change needs to keep going for culture and process excellence. This takes some vision and persistence in leadership until the change (lean) is self-sustaining.

Celebrate Success

Although *"a long journey starts with a single step"; "a single step doesn't guarantee the long journey"* (Heath & Heath, 2010, p. 251). It is necessary to celebrate the first step, the first win. This however is easier said than done because of peoples' predisposition to criticise, to point out what's wrong with a change (Ackoff, 2003) instead of looking at what went well. Although some reflection and constructive critique is necessary (Liker, 2004, p. 257); when managing a transition, it is important to keep looking for bright spots (Heath & Heath, 2010, p. 251). This requires *"a clear view of the destination" and* for the leadership to be *"savvy enough to reinforce the bright spot behaviours when they happen"* (p. 253).

Feeding Change and Removing Obstacles

Leveraging the small wins, engineering success and generating hope can be used to feed ongoing change. Generating the small wins and linking them together maintains hope, sense of progress and keeps the change going. It is desired that the change eventually may become self-sustaining and not purely top-down drive.

There is evidence that change feeds on itself even beyond the reinforcing of the successes or wins. Kelman's work on Unleashing Change (Heath & Heath, 2010, p. 254,255; Kelman, 2005) gives the following points for the snowballing effect of change:

> The "*mere exposure effect"* – the more you are exposed to a thing the more you like that thing e.g. Eiffel tower first Parisians hated it but *"public opinion evolved from hatred to acceptance to adoration"*, this is growing accustomed to something.
>
> Also "*cognitive dissonance"* – People A. don't like to act in a certain way and think in another so once a step is taken people find it hard to dislike the way they are acting. And B. as they think of themselves differently their "identity evolves"

Further to this, there is the need to remove obstacles. The *principle obstructions* (Ackoff, 1981) need to be cleared; these include structure, poorly designed incentive schemes (misguided KPIs), and persons that hinder change (Kotter, 1995; J. P. Womack & Jones, 1996; Joiner, 2011; Hines et al., 2008)

Group Effects and the Guiding Coalition

In situations of uncertainty, where the appropriate behaviour is unclear, people tend to follow the crowd. Hence, to indicate the normal behaviour, buskers and bartenders plant coins in their hat or tip jar. These group effects can greatly threaten permeability of change or it can be used to enhance it. The social signals can either guarantee or doom a change effort (Heath & Heath, 2010, p. 228); the right behaviour needs to be advertised (p. 229). Kotter's (1995) process for change advocates forming a "*guiding coalition*". It is also beneficial to form small groups that promote the change, creating *"free spaces"* for "*reformers"* (Heath & Heath, 2010, pp. 246, 247; Kellogg, 2008). Engineering some positive group atmosphere(s) enables change to spread without the choking effect of negative influences. Some lean authors and practitioners advocate removing negative persons as soon as possible because of the devastating effect they may have, creating negativity that hampers an organisation to move forward (Joiner, 2011; J. P. Womack & Jones, 2003). These free spaces and guiding coalitions, become groups that enable the cultivation of the new identity with its ideas and language to promote change in the organisation. Unfortunately, this may create a negative feeling in others; an us versus them identity crisis may be necessary.

Utilising the Crowd

The influence of the crowd may outweigh the influence of management commitment in some cases. This was seen when comparing the sustainability of change in two hospitals (Kellogg, 2008). The purpose was to reduce the long hours medical interns would work. At one hospital 42% of the superiors supported the change and at the other 66%. However, the one with the greater senior support failed. The situational forces that enabled free-spaces enabled the change. Small groups moving around the hospital enabled the cultivation of identity and language for change even though there was less management commitment. Management may commit to a change, but this general commitment may not be enough. Leadership initiative, like engineering positive groups, may be needed for successful change.

2.8.5 Additional Factors

Recent thorough review of the literature uncovered many additional factors (Oreg et al., 2011). Particularly relevant or demonstrative are: management support, management commitment, social support, trust in management and trust in colleagues; job control, variety, complexity, value, satisfaction, ambiguity, conflict and overload; staff and management competence, change frequency and communication; product and service factors, customer satisfaction, perceived organizational support, teamwork, merger or acquisition factors; organisational type, justice, systems, self-esteem, identification, information and discrepancy; amount of participation and perceived benefit or harm. In this section, a few pertinent but additional factors are mentioned in more detail.

Planning for Stages of Change

One factor to consider is the progression of change with time. It was discussed that advocates for continuous change disagree with understanding change as having discrete stages. Their point of view is valid but, in general, *different factors are going to be important at different times in a transformation,* and models have been developed to explain a staged process. For the benefit of leadership preparation and a recipe for successful change, these staged models are beneficial. Although they may not exactly present the continuous nature of change, they are helpful for practitioners.

Kotter (1995, 1996; 2002) prescribes a generic eight step model for leading change. Kotter's model is adaptable, popular and has widespread acceptance (Harris, DeRosa, Liu, & Hash, 2003). Kotter's eight stages are: 1. Establishing a Sense of Urgency; 2. Creating the Guiding Coalition; 3. Developing a Change Vision and Strategies; 4. Communicating the Vision for Buy-in; 5. Empowering Broad-based Action; 6. Planning for and Creating Short-term Wins; 7. Never Letting Up (consolidating and producing still more change); and 8. Incorporating Changes into the Culture (connect change to success).

In this popular stage model, there are many of the aspects of change already discussed. The model itself shrinks the challenge for a change agent, scripting the critical moves to generate a successful change.

Although this model is useful in a generic sense, there is still a need for models to give practitioners "handles" for specific scenarios of change.

Effects of Changing Expectations

Goal setting for developing people is a key responsibility of the change leader. This means moving personnel out of their comfort zone enough to stretch them without causing anxiety. (Hines et al., 2008) In lean, worker empowerment is high. This means responsibilities like control of quality and process improvement is given to employees that previously were considered of low skill and had low expectation. This is generally praised as engaging and positively motivating staff (M. S. A. Purdy, 2005) but there is other evidence employees may find the new responsibilities stressful and more demanding (Delbridge, 1998). Employee characteristics can mean a motivator for one employee becomes a demotivation and source of resistance in another. Additionally, if a change lessens responsibility, required commitment, or other rewarding factor; the prior conditions may be perceived as better and staff can be committed and satisfied with the old way (Oreg et al., 2011). These changing roles and expectations need to be considered.

Supporting Factors

In both the lean and organisational development literature methods, tools, and processes that support change or can be used in a supportive way. These are related to and are the further leveraging of previous points to maximise beneficial effects and minimise detrimental effects.

Present a Simple Vision for Clear Direction and Motivation

The vision should be simple, not too complicated and clarify the direction to move in (Heath & Heath, 2010; Kotter, 1995). Once the vision is there and aligned to strategy, then the vision needs to be communicated intensely using every opportune moment (Kotter, 1995). Use staff meetings, performance reviews, banners and every opportunity.

Visual presentations that hit home and grab attention turn the vision to feeling. Physical artefacts can be used, or visits to see the real situation or effect of a person's behaviour on others. Not forgetting the grander vision is balanced by making change easy, simplifying the steps so everyone knows "this is what we do next". The sense of progress can also be leveraged in presenting the vision, like with loyalty card that starts with two stamps. This installs confidence that the change is possible. (Heath & Heath, 2010)

The ideal vision may be a merger between the motivation of a BHAG (Big Hairy Audacious Goal) (Porras & Collins, 1994) and the execution of S.M.A.R.T (Specific, Measureable, Attainable, Timely/Time-bound) goals (Doran, 1981). Heath (2010) advocates for setting *destination postcards* that shrink the change, giving whilst clear direction and motivating towards the goal (p. 93). This should let people know where they are going and what the need to do now. Leaders are advantaged if they have developed the ability to sell this kind of vision (p. 79).

Strategy and Alignment with Policy Deployment

Strategy is fairly useless without staff alignment, and alignment is promoted with policy deployment. Strategy requires an assessment of the situation, forming of a vision for the future and an understanding of the transition to take place. Whereas alignment is ensuring, those who are involved know and understand the strategy. Key Performance Indicators (KPIs) are typically used for aligning individuals with the strategy. Strategy, KPIs, and improvement activity should be linked together. This requires a deployment of policy for alignment of the organisation. Visual management techniques, like A3 management, can be utilised for this. With this method, everything important to a particular facet of the organisation is displayed and measured on a single A3 sheet. For long term success, the PDCA (Plan, Do, Check, Act) cycle (Deming, 1986, p. 88) ensures strategy is correct and alignment is achieved. (Hines et al., 2008; Liker, 2004). This is all part of the communication process, which is critical for engaging staff and building a learning organisation.

Communication Process

In lean implementation the desire is to develop a learning organisation (Hines et al., 2008; Liker, 2004), a kind of collaborative learning environment (Regan & Schroeder, 2012). In such an environment, communication appears to be king. The Toyota Way is marked with having extremely effective and efficient processes for communication (Liker, 2004). Recent research recognises *"there needs to be a coordinated effort on the part of quality leaders and all team members to apply this learning to the day-to-day"* (Schroeder, 2012). This collaborative learning is supported by specific communication processes.

For communication of strategy, change leaders are encouraged to ladder their *"way down from a change idea to a specific behaviour"* (Heath & Heath, 2010, p. 63). This is to break down the strategic goal, a large problem, into smaller projects and then again into smaller problems for action. The strategic goals (the large problems) at the top level are embedded in particular problem solving projects (for the medium size problems) which are solved by regular improvements (addressing many small problems) (Hines et al., 2008,

p. 25). Interactively using lean methods of A3 management (concisely reporting and problem solving on a single sheet of paper), along with the catchball or nemawashi process facilitates wide spread communication and consensus can be achieved for alignment of initiatives to strategy (Hines et al., 2008; Liker, 2004).

Reviewing the many resources on Toyota impresses the reader with what lean thinking is. In the TPS, it is fascinating how the communication process, along with other systems and procedures, are designed to promote organisational learning. These seem to provide the rules for a dynamic organisation at the *"edge of chaos"* as discussed by Burnes (2005).

Developing a New Identity with the Growth Mindset

One issue with change was peoples' confidence in their ability to pass through it. There are at least two-routes for building peoples' confidence so that they feel "big relative to their challenge". One is to shrink the change and the other is to grow the people. This is to make the change smaller or the people bigger (Heath & Heath, 2010, p. 176). Developing a new identity for staff is part of having the growth mindset, acknowledging people can improve. The key is to adjust the way people think about themselves. This is done by appealing to or creating an identity that will direct them. If the right identity is developed people will feel behave accordingly. Calling people by a new title is one way of developing a new identity. Studies even showed how accepting a bumper sticker or signing a petition appears to change the way people thought about themselves, associating them with a new identity. The way children think about themselves academically can be adjusted by referring to him as a "scholars", those who seek "excellence" (p.75, 219). In the same way, factory production line workers have been aligned with business goals to bring forth improvement initiatives by giving them an "inventors" identity. Such identity can be supported by a title or form of certification (Heath & Heath, 2010, p. 158).[38] In principle the adjusted identity promotes positivity amongst the staff, the type of people they are, the way they behave, and a satisfaction in the kudos, responsibility and feeling of contribution that the identity brings (M. S. A. Purdy, 2005).

Supporting Habits: Modify the Environment and Building New Habits

Changing the environment is an easy way of removing obstacles and shaping the way making desired new behaviours easier or even automatic. The environment may include item checklists, procedures, reminders, systems (e.g. kanban) and brief regular meetings (e.g. stand-up meetings). Engineering these things in the environment promotes the behaviours required and reduces the level of self-control needed to maintain the change. Whether controlling eating by controlling bowl size (Wansink & Kim, 2005; Wansink & Sobal, 2007), or marking lines on a factory floor to trigger appropriate behaviour (Heath & Heath, 2010, pp. 213–214), these habits and prompts make desired behaviour easier.

Although people think of habits as being negative, there are good habits. Habits can be considered *"behavioural autopilot," "they allow lots of good behaviors to happen"* without sapping a person's self-control (p. 207). Modifying the environment means the adjusted situation and its forces (Lewin, 1947) can

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[38] Later case studies tested this with an "Improvement Engineer Program" (see 4.2.2 Case B—Company B).

shift habits in the right direction. One example is adjusting an office arrangement to promote collaboration; but there is also a mental aspect to habit forming seen in setting *action triggers* (ref. Gollwitzer, 1999; Heath & Heath, 2010, p. 210). For example, someone may make the decision to go swimming every day after dropping their kids to school (p. 209). This is an action-trigger that makes the decision pre-loaded and conserves the amount of self-control needed. In lean manufacturing, the visual systems provide action triggers. This is seen in methods like kanban, 5S, the display of checklists and procedures (standard work), and other visual systems. These direct the appropriate behaviour and make easier. So again:

> "*A good change leader never thinks. 'Why are these people acting so badly? The must be bad people.' A change leader thinks, 'How can I set up a situation that brings out the good in these people?"*
>
> (Heath & Heath, 2010, p. 220)

This is the kind of growth mindset needed for producing a lean learning organisation.

Method Selection: Sense of Progress More Important than the Numbers

Related to small wins was achieving a sense of progress. This can be more important than doing what is logically best by the numbers. This can be illustrated by the "Debt snowball". The Debt Snowball is a method for persons trying to pay off a number of debts. According to the accounting perspective, the first debt one should pay off is the one with the highest interest. According to the debt snowball method you make the minimum payment on all debts and then pay off the smallest one first. Financially this is wrong, but motivationally this method means wins are achieved as early on as possible i.e. bite off some small things get the sense of progress going.(Heath & Heath, 2010, p. 131; ref. Ramsey, 2007, pp. 114, 116–117)

This logic is relevant to the design of a lean implementation. It is important that the methods will generate the initial wins to get progress going, i.e. providing the motivation to go on. This discussion indicates method selection should not be based merely on what is the best tool for performance enhancement. Rather decisions should consider the *benefits and detriments to employee development at in the situation and stage* of an implementation.

> Implication: Tools implemented first may not need to address the most significant hurdles or even most critical of challenges for success but should provide small wins, building confidence and a sense of progress.

Creating Lean Promotion Functions

Creating of lean promotion functions that report to a change leader has been advocated. This is to give responsibility of change to someone from each function. *This may be an issue of larger organisations and not the SME context like New Zealand.*

Some advocate for a dedicated lean Implementation or Continuous Improvement Programme team. Recent discussions have pointed to problems with this (Linkedin, 2012). A dedicated team lends to an "us" vs. "them" approach (Heath & Heath, 2010) whereas the purpose is to get the whole organisation working on the same goals, all staff empowered for change, not just an elite group of industrial engineers. This also points to the need to develop standard terminology for departments; a quality department may talk about the same things as lean promoters but with different terminology and thus creating confusion (J. P. Womack & Jones, 2003, pp. 256–257). A holistic lean approach that encompasses all functions is preferred.

2.8.6 Internal Resources and the Nature of the SME

The Change Leader and their Capability

The leadership of a change agent should be one of a long term view, technical virtuosity and a passionate to succeed (J. P. Womack & Jones, 2003, pp. 97, 115). However Womack (2003, p. 268) discusses that the change agent may need to step down after initial change. That is as the organisation switches over from top down initiatives driven (the first stage of a project) to bottom up initiatives driven from employees, a systems manager is needed for the pulled changes rather than an initiative pushing change agent. However Hines (2008) seems to stress that right from the early stages a change agent would hold off and give the ownership of change to the employees through much emphasis on culture and less emphasis on the initial wins. However, both agree that leaders being coaches and employees being proactive are the keys to a self-sustaining organisation (J. P. Womack & Jones, 2003; Hines et al., 2008). The organisational change literature promotes the skill and capability required from the leader of transformational change (Ackerman, 1986).

Organisation Demographics and Resources

The situational variables for an organisation cannot be neglected. For example, size, location, number of employees, product mix, and any number of factors could affect implementation success. Available resources should also be included: that is physical resources, financial resources, and human resources including capacity for change and innovation to name a few. (Oreg et al., 2011)

The SME: Requirements, Restrictions and Benefits

Regarding small business, it is recognised that aspects of change that are specific to their size. On the positive side these include a typically flat structure which is seen to promote flexibility and ease of dissemination of knowledge (Marzec & Matthews, 2012). On the negative side, there are limited resources both in staff and capital as well as the vulnerability to key staff migration. If there are only a few key employees and one moves onto other opportunities that can spell great loss to a small business. A specific focus of this work is on assisting small businesses who have particular restraints and specifically limited resources for leading change. As confirmed (Achanga, Shehab, Roy, & Nelder, 2006; Goodyer et al., 2011; Rose et al., 2010, 2011; Singh, Garg, & Deshmukh, 2008; Thomas et al., 2008).

This highlights the need for small business owners, operators, and managers to own the knowledge of lean for successful implementation.

2.9 Appropriate Leadership: the Coach, the Commitment, Strategy and Knowledge for Change

Although the entire context of making change involves the skills of leadership and the actions they take, there are a few key factors to mention regarding them. These particularly address their attitude and actions as highlighted in literature and practitioner experience.

2.9.1 Being a Coach

> *"Change begins at the level of individual decisions and behaviours, but that's a hard place to start because that is where the friction is."*

This quote (Heath & Heath, 2010, p. 56) points to the need of leadership to give clear direction for tough change situations. This means, setting the strategy as the big picture and then taking the hands off is not appropriate for a successful transformation. It is the fine details where the paralyzing takes place (p. 53). This does not necessarily mean giving the answers every time, but giving clear direction of what is expected. At Toyota, there is the coaching for a growth mindset. This is exhibited when a sensei will leave a new engineer to struggle with a problem, to hone his skills rather than be handed the answer (Liker, 2004). The key in being a change leader is being this kind of coach.

Leadership defined as coaching is different from the management approach in the business world. In this results orientated business mindset it is spontaneous to reject the need for a learning and practice stage. However *"to create and sustain change, you've got to act more like a coach and less like a scorekeeper"* (Heath & Heath, 2010, p. 168), recognising that *"everything can look like a failure in the middle"* (Kanter, 1999). A coach anticipates reactions and prepares how to respond to the situations that arise (Ackerman, 1986). The coach recognises the possibility and psychology of failure and instils a growth mindset for ultimate success.

2.9.2 Commitment from Leadership

The importance of management commitment is expressed strongly in literature. The work is summarised well by Worley & Doolen:

> *Though many variables may affect the success of a lean manufacturing implementation, many researchers agree anecdotally that commitment by top management is vital (Alavi, 2003; Bamber and Dale, 2000; Boyer and Sovilla, 2003; Parks, 2002; Womack and Jones, 1996). Management that fails to embrace the implementation may intentionally or unintentionally sabotage the effort (Boyer and Sovilla, 2003; Stamm, 2004). Top management should not only demonstrate commitment and leadership, it must also work to create interest in the implementation and communicate the change to everyone within the organization (Boyer and Sovilla, 2003). Management must be visibly connected to the project and participate in the lean manufacturing events (Alavi, 2003; Boyer and Sovilla, 2003; Emiliani, 2001). A lack of investment by upper management in the lean manufacturing*

> *implementation may also affect the success of the implementation in less visible ways. If employees feel that the executive team does not respect their efforts, discouragement may take hold and the lean manufacturing effort will fail. Though it is often desirable to drive change from the factory floor, it is important that a transition to lean manufacturing be driven by the executive management team (Boyer and Sovilla, 2003).*
>
> (Worley & Doolen, 2006)

It is proposed that sustainability is reliant on someone positioned appropriately and with a commitment to change; senior management need to take the responsibility to lead the change (T. A. Boyle et al., 2011). Hines et al. (2008, 2011) also stresses demonstration of management commitment. Dr. Jeffery Liker rates the failure to do this as one of the top five mistakes in implementing lean (Balle & Balle, 2009, p. vii). A serious commitment in words and deeds is needed by the senior team. Kotter (1995) states:

> *"Nothing undermines change more than behaviour by important individuals that is inconsistent with their words"*

The role of management in the context of lean implementation was clearly a key factor to address.

2.9.3 Leadership Lean Knowledge and Commitment

The amount of lean information managers are exposed to has been indirectly related to success through commitment by a statistical model, i.e. (T. A. Boyle et al., 2011). Lean knowledge is obtained through exposure to various information sources—training, teaching, observation, and experience. Undoubtedly, training includes aspects of teaching and experience. Teaching, as defined here, is from external sources and is acquired by presenting oneself to a teacher or by taking a self-taught approach, exposing oneself to external information sources. A coach as understood here is one who is developed so that they can typically teach and train by leading through experience. It has been seen that an increased exposure to lean knowledge or information correlates highly with management commitment to lean leadership. Further, through lean commitment by managers, exposure to information sources has been was indirectly related to a true strategic approach, engaging deeper lean thinking.

> *Overall, it appears that the greater the management exposure to the current management literature, the more we saw support for lean improvements and evidence of the company moving from simply implementing individual lean practices to lean thinking.*
>
> (T. A. Boyle et al., 2011)

The study of Boyle et al. (2011), acknowledging the enormous change process of implementing lean, set out to explore why managers are holding back from embracing lean and considered variables related to exposure to lean information sources. Of the many ways managers can be exposed to lean information, Boyle et al. (2011) highlighted conferences, training sessions, plant tours and internal workshops. They found that narrower managers tended to explore technology (e.g. trade shows) more than manufacturing strategy based techniques such as lean. This study focused on businesses of over 50 employees, manufacturing in Canada and had 109 responses. The study showed no significant difference between process focused (low volume, high product mix), product focused (high volume, low product mix) and mass-customisation (high volume, high product mix) strategies. A lack of commitment to formal lean programmes was noted (30%) and the analysis of data showed that *"management's use of external information sources and their commitment to lean are mediator variables between a number of internal and external drivers for lean and lean thinking"* (T. A. Boyle et al., 2011).

> *Specifically, our final model confirms that management exposure to external information sources and commitment to lean both influence the extent that lean thinking exists in the organizations. However, the direct relationship between external information sources and lean thinking is not supported. Instead, an indirect relationship exists, where increased exposure to sources of lean information increases management commitment to lean and ultimately the extent of lean thinking in the organization.*
>
> (T. A. Boyle et al., 2011)

Their study found that external pressures, despite not influencing use of information sources, did influence commitment to lean. And their structural equation model (T. A. Boyle et al., 2011) suggested that, regardless of the pressures internally or externally or the innovativeness of a company, it was only by *"visible management commitment to lean"* that the necessary resource such as employees, capital, and time would be released for successful lean implementation. Management commitment explained 34% of the variance in lean thinking.

> Managers are required to provide the leadership for change, so their exposure to information sources implying knowledge of lean with commitment to lean may be the key to implementations success. Success of lean requires knowledge of lean best practice which includes process, tools, and technology but more so strategic, leadership and engagement factors that are less easily seen, the factors for generating culture excellence.

The literature review did not uncover other research of this type. The Lean Enterprise Institute (LEI) does list "get the lean knowledge" in their Lean Action Plan, as below:

> ***"Get the lean knowledge,*** via a sensei or consultant, who can teach lean techniques and how to implement them as part of a system, not as isolated programs."
>
> (LEI, 2013)

This is listed after find the change agent whereas the author believes that lean knowledge should be primary in the process. Specifically that leadership would drive change without being disconnected from the organisations activities, i.e. the primary change agent although another agent may represent management on a more regular basis. The stress of consultants in the LEI statement is on getting knowledge from a sensei or consultant. This reliance on a Sensei and not broader knowledge sources is risky, "hit and miss". The more expanded action plan in Lean Thinking (J. P. Womack & Jones, 2003, p. 247) cautions choosing consultants that are driven by financial interest (i.e. won't challenge leadership) or after quick win solutions. It mentions that all parties should develop an understanding of lean. The knowledge and understanding in these action plans point to techniques rather than the below the waterline aspect and organisational development. Although the work is insightful and added significantly to the body of knowledge, it is still contextual, based on a selection of case studies and experiences. The plan is from their own case studies and reliance on George Koenigsaecker's essay (Koenigsaecker, 1997; J. P. Womack & Jones, 2003, p. 247 see footnote reference to George Koenigsaecker). Their up-to-date work does stress not having a tool focus (J. P. Womack, 2007). There are still gaps in the understanding of what the real effect of knowledge and other factors are.

Although there is much work and general agreement concerning the vital importance of management commitment to lean, there have been few studies on lean knowledge and specifically management knowledge, as a critical success factor (CSF). <u>The specific importance of lean knowledge as opposed to commitment was thus identified as a core component for this work</u>.

2.10 Implementation Decisions and Risk Management

As well as addressing broader stroke organisational change, lean implementation involves many decisions that are situationally specific. One challenge is deciding which of the many lean tools to apply and when to apply them. This is complicated by the considerations of change management. Every step of an implementation has positive and negative consequences.

In effect, this section highlights that lean implementation is a decision making process requiring risk management. The intersection between strategic risk management and lean implementation is explored.

2.10.1 History of Risk Management

Risk management as a quantitative practice (i.e. more than gut feel) began following the emergence of probability theory and statistics in the 17th century. From the 18th century well into the 20th century, risk assessment was practiced in a limited way, in insurance, banking, and financial spheres and possibly public health. However, since the 1960's the methods have been developed and adopted in a large proportion of medium and large sized enterprises. This usage has been for the strategic benefits but also to meet compliance requirements. Insurance buying was the early form of risk treatment, but is now relied on less than it was in the past. Other methods of control are being preferred. Methodologically there has been a shift to integrate the technical and financial sides of risk management under one function. And in addition to quantitative, qualitative methods of risk analysis exist. Both methods need to be applied with a degree of caution. (Hubbard, 2009, p. 21; Surrey, 2012)

2.10.2 Risk Management for Decision Making

Risk and strategic risk management are defined in the realm of uncertainty, risk, and reliability. There has been some difference regarding definitions in literature (LeRoy & Singell, 1987). Difference stems particularly around the seminal work of Knight (1921) and more recently around risk management standards. In risk management, the traditional emphasis was on scenarios where outcomes are significantly negatively. The concern with lean is not only *the probability and magnitude of outcome(s)* (Hubbard, 2009, p. 8) from an undesirable event but also the desirable. This work aims to maximise what is desirable in terms of lean implementation success and mitigate what is undesirable in terms of failure.

Standards produced have defined risk in the sense of both negative and positive aspects (e.g. PMI, 2000; ISO/DIS 31000, 2009; PRAM, 1997). Although some differ on this, critics still agree that risk analysis can and should be combined in the overall decision making function of an organisation (Hubbard, 2009, pp. 89–90, 242–244). Using common tools, the decision making processes can be managed for both the positive and negative outcomes of uncertainty. Although some have called this mutilation of language, it could be considered the development of language. Therefore in this work the definition of Hubbard (2009, pp. 10, 27) is modified for positive cases also:

- The identification, assessment, and prioritisation of risks followed by coordinated and economical application of resources to treat the risks appropriately - to maximise the benefits and minimise the detriments of uncertain outcomes.

This broadens risk analysis to decision analysis. Decision making theory addresses all critical decision making not just mitigating risks in the negative sense (Douglas & Jones, 2007; Doyle & Thomason, 1999; Hansson, 2005). This is in line with the standards (ISO/DIS 31000, 2009; PMI, 2000; PRAM, 1997). Hence, risk involves *the positive or negative effect of uncertainty on objectives* (AS/NZS ISO 31000, 2009).

Critique of Risk Management: Contemporary Methods and Application

There are various criticisms of risk management methods and their application. One critique of risk methods is the skewing of analysis to support someone's own cause and self-motive. Examples where hidden motives are present are justifications for oil drilling (Heath & Heath, 2010, p. 89) and building nuclear power stations (Flyvbjerg, Bruzelius, & Rothengatter, 2003). Overweighting of supporting subjective estimates lends to confirmation bias (Nickerson, 1998). Psychological and political reasons are likely to account for the skew towards inaccuracy, for example optimism bias, and pressure for strategic gain (Flyvbjerg, 2006).

Evidence and industry practice suggests that management perceive risk as something intangible and not measureable. Hubbard (2009, p. xi) suggests techniques based on measurements have not been communicated to the wider audience. For accuracy of risk management models, there is need for critique of the method itself. "At least I am doing something" is not a good enough excuse, <u>practitioners need to ensure what they do is accurate to the extent that it is relied upon.</u> Severity and especially probability are key concepts to risk analysis and both are difficult to get a grasp of. If the event is common, it is easier to estimate. However, risk managers rarely are dealing with high frequency low cost risk, but more commonly rare and high consequence events (p. 42). Because of this, it is difficult to determine how sound a risk method is by intuition.

Risk Analysis Methods

Methods can be categorised according to their scientific merit, i.e. less reliance on the experts gut feel. The first and least scientific is expert intuition, followed by expert auditing, and simple stratification methods (basic scales e.g. for heat or risk maps and matrices). Following this are weighted scores, traditional financial analysis, and calculus of preferences (better but still relying on expert judgement). Finally are probabilistic models like Monte Carlo Analysis (Hubbard, 2009). Consultants of risk management wield and even develop tools with little real understanding of the field. This is similar to many so called lean consultants. In risk management, it is important to fully understand a methods use and its pitfalls along with ensuring the assessment is sufficiently complete.

Although sound scientific quantitative methods are ideal, some organisations do not have the resources required. Small organisations may lack resources for the task at hand (Goodyer et al., 2011; L. C. Hendry, 1998) let alone the risk assessment or costly outsourcing of that task. There are also time restraints to consider. So there needs to be a simpler way of ranking and recognising the threats and opportunities for benefits and detriments and planning to treat them without compounded complicated mathematical models.

Qualitative methods typically rely on expert opinion and intuition to support assessment and the decision making process. No doubt, the less risky solution is a properly designed Monte Carlo style model, checked against history; then verified, and double checked with actual measurements (Hubbard, 2009). However, qualitative methods have their place with proper care and use of the variables, not stretching the arithmetic beyond what is reasonably sound (Pons, 2010a; A. J. Ross, Davies, & Plunkett, 2005).

Expert opinion is flawed, as particularly obvious in studies of self-estimate (Heath & Heath, 2010, p. 113), however methods can be incorporated to correct through training and calibration tests (Hubbard, 2009, p. 46). Optimism, among other bias, can be corrected with methods like *reference class forecasting* (Flyvbjerg, 2006). This Nobel prize winning method suggests focusing on how similar projects performed in the past (Kahneman & Tversky, 1977, 1979; see Kahneman, 1997), this in effect is striving for an external objective measurement as is essential (Hubbard & Samuelson, 2009; Hubbard, 2009).

AS/NZS ISO 31000 Standard

The body of knowledge on risk has been summarised in the ISO 31000 Standards. The AS/NZS 4360:2004 was used as the first draft for the ISO 3100:2009. The New Zealand rendition (AS/NZS ISO 31000, 2009) has only slight variations from ISO 3100:2009. The standard went through much review and supports *"a new, simple way of thinking about risk and risk management"* as well as addressing "*inconsistencies and ambiguities that exist between many different approaches and definitions"* (G. Purdy, 2010). Looking at the entire management system, the standard supports not only the design and implementation of risk management processes but its maintenance and improvement.

In addition to unifying terminology, the AS/NZS standard gives principles and guidelines for risk management. It does not prescribe the specific tools and methodologies but does guide in general processes, giving points and brief explanations to consider and explore. The standard consists of the principles, the framework, and the process for risk management. The earlier standard, AS/NZS 4360:2004 (the base of the current standard), was supported by the accompanying handbook (ASNZS (2004) HB 436 2004 Risk Management Guidelines). This is still beneficial to reference with the current standard.

ISO 31000 Criticisms

The standard does promote a unified language which is beneficial but poses challenge for those who use other unique language (G. Purdy, 2010; Hubbard, 2009, pp. 88–90). The standards have also come under criticism for not proving or having a measurable improvement on risk (Hubbard, 2009).

2.10.3 The Intersection of Risk and Lean Management

Although risk management is being used broadly, there are a limited number of research publications linking *Lean* to *Risk*. Articles discussed the *benefits* and *detriments* of factors to success (M. Boyer & Sovilla, 2003) as well as discussions of success factors for lean and lean implementation in general (Hines et al., 2008; Liker, 2004; Schmidt, 2011; J. P. Womack, 2007), specific considerations for SME's (Achanga et al., 2006; Burke & Gaughran, 2007) and other demarcations (Glover, Farris, Van Aken, & Doolen, 2011). Innovative frameworks and manufacturing techniques, e.g. core competency based framework (Parry, Mills, & Turner, 2010) and emergent manufacturing methods (Ahmed, Sawhney, & Xueping, 2007), have been applied to reduce specific risks. Comparisons were made between risk and lean process cycles (Seddigh & Alimohamadi, 2009) and lean methods have been used to identify and treat uncertainties in construction projects (Qiu, 2011; Wells, 2010). Processes, including supply chain focused modelling and simulations, have been used to support the mitigation of risks (Hallam, 2010; Mahfouz, Shea, & Arisha, 2011; Shukla, Tiwari, Wan, & Shankar, 2010) and *"reduce the risks of the implementation process"* (Mahfouz et al., 2011). There are also recent studies in supply chain risk comparing large and small enterprises (Thun, Druke, & Hoenig, 2011). However all these works are at the best treatments for maximising benefits and minimising detriments of single, specific aspects of a lean system e.g. specific processes or supply chain. These did not actually perform any structured risk analysis of an implementation besides this bounded kind of optimization.

The closest links to a risk assessment of lean implementation was risk and reliability method use, acknowledgement of risk consideration being required for lean systems, and the use of Program Management as below.

1. Use of FMEA (failure modes and effects analysis) reliability tool (Lombardi, 2011; Sawhney, Subburaman, Sonntag, Rao, & Capizzi, 2010).
2. Use of Monte Carlo analysis in ship yard processes (Kolic, Fafandjel, & RUBEA, 2011).
3. The matching of lean systems strategy with risk identification. Taking a systems engineering approach to optimise for risks in the whole (Justin, 2006).
4. And the use of the Program Management system/process which came closest to an ideal risk management approach to Lean implementation (J. L. Wilson, 2004).

Sawhney et al. (2010) found in reliability that *"practical methodologies to improve the reliability of lean systems are non-existent"*. Their work did develop a *"Risk Assessment Value (RAV)"* for Lean systems and developed a *"modified FMEA for the four critical resources"*.

It has been suggested to merge lean thinking and "high reliability" (Smart et al., 2003) to balance the non-buffered, *fragile* nature of Lean (Krafcik, 1988). This can be achieved through risk assessment and management. However, there is at best little evidence of steps in that direction.

In summary, reviewing the literature[39] there was little to no application of a standardised risk assessment to lean implementation.

Risk management has been used in other similar fields as a support to the decision making process. It is beneficial to consider these applications as examples close or relevant to this present work.

Immediate Relatives

The most similar fields to lean are really JIT and agile manufacturing and a distant cousin, once removed, may be Theory of Constraints. No applications of agile manufacturing risk management were found, the others were similar to lean i.e. limited application of risk assessment and treatment in discrete scenarios only but not a holistic risk management application to implementation of the method (examples: for JIT see Pet-Edwards, Thompson, & Panathula, 1999; for TOC see Ruan & Qin, 2011). Indications are there is little application of a standardised risk assessment to a continuous improvement implementation "project".

These methodology or strategy implementations (lean, JIT, agile, and TOC) are in essence organisational changes. A search for "organisation change risk" goes further than the previous searches. This identifies multiple applications of risk management and related methods to a variety of change projects. To save digressing further this is better classed in project management. There is much literature on risk in project

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[39] Searches included four main sources: Google Scholar "http://scholar.google.co.nz" , Sage Publications "online.sagepub.com" , Compendex "www.engineeringvillage2.org" and Science Direct "www.sciencedirect.com"

management including relevant standards (PMI, 2000; PRAM, 1997). This area is worth mentioning as lean implementation is in essence a change project to manage.

Application in Agile and Plan Driven Projects

Similar to a lean application is the risk management application to *agile* and *plan-driven* software development methods. As with lean production, the methods of agile and plan-driven development have shortcomings that are dependent on the situation. These short comings need to be addresses in order to minimise chances of failure and maximise opportunities of success. Boehm and Turner (2003) proposed that by risk analysis methods a tailored approach to development could be arrived at, one that enables developers to "*enjoy the benefits of both agile and plan-driven methods, while mitigating many of their drawbacks".* They determined that: *"Focusing test effort on the high-risk parts… can generate project time and effort savings"* (Boehm & Turner, 2003). Their approach was to plot critical factors using quantitative and qualitative assessments to form a Polar Home Ground Chart. The chart mixes quantitative and qualitative data and hence is essentially a qualitative method.

2.10.4 Gaps in the Lean-Risk Body of Knowledge

Our review was specifically for the intersection of risk and lean and in that sense not a thorough analysis of the risk management body of knowledge (BOK). However, one gap in the general risk management BOK is the disparity between the various fields of practice and research (e.g. insurance and finance). Although standards have come some way to address this, there is a variety of approaches and rigour applied.

Additionally there is a gap between research and practitioners. This is seen in the lack of sound methodology used by practitioners. This is similar to the work on lean sustainability where consultants wield tools without understanding of the limitations and failure.

The gap is then that research fields are disconnected from each other and the practitioners are disconnected from the research and knowledge of proven methods and appropriate techniques.

Risk Management Needs Application for Lean Projects

Risk analysis and management is seen as being critical to all serious decision making processes. However, there has been little to no documented application or study of risk assessment in the lean implementation BOK. This simplifies the report in one perspective but points to a great gap in the body of knowledge. Besides the risk of overall implementation failure, there are the risks at each facet and stage. It is believed that each aspect should pass through a risk assessment and analysis of some kind to determine treatments necessary. A risk analysis for lean implementation has been developed within a case study (Pearce & Pons, 2013).

2.11 Literature Outcomes

2.11.1 Background

Lean management is becoming the standard for systematic productivity improvement. The basics of lean can be described in two key principles:

- Lean is waste elimination.
- Lean is respect for people.

Lean prescribes a journey towards perfection through eliminating waste or wasteful action. It has some key principles and accompanying tools as seen in the Toyota Production System and as adapted to fill prescribed functions in a lean system.

Five key principles for the elimination of waste were provided in Lean Thinking (J. P. Womack & Jones, 1996):

1. Define value
2. Map the value stream
3. Develop flow
4. Implement pull

These four steps become a cycle to perfection. This is linked to the PDCA (Deming, 1986, p. 88) for continuous improvement. This lends itself to goal setting and review of various forms. And points to:

The *journey view* for continuous improvement.

Lean as a strategy for production improvement originated in the mass production setting of the automobile industry, specifically the Toyota Production System. It was useful to see key elements of lean as they developed to current state. Specifically:

- Japan after World War II had specific conditions with limited resources.
- This necessitated innovative thinking to produce more with less; they removed wasteful actions of the western system and still provided necessary variety.

Lean has undergone various critiques. Typically, these critiques were from studies that neglected the development of lean or were simply weak and biased. Critiques that were more relevant are:

- Does lean possess scope and strategic perspective?
- Does lean possess contingency?
- Is lean really universal?

The scope and strategic perspective of lean is critiqued due to misapplication of lean as purely tools and processes. The critique of lean lacking contingency for its application beyond mass production has some standing. Contingency is linked to universality, which is lean's usefulness not just beyond mass production but beyond manufacturing into every enterprise. It is determined that:

- The concept and principle does not lack contingency in itself. The way lean is applied is what appears to "lack contingency".

Additional models are needed to assist with implementation in specific situations. It is believed these models can provide the necessary contingency and show universality of lean. This is seen as key to distributing the knowledge for lean success.

2.11.2 Lean and Organisational Change

What is common to continuous improvement methodologies is unfortunately the large number of implementations that fail to sustain. When lean is adopted in traditional manufacturing and service organisations, it requires a widespread organisational change. Due to the neglect of proper change leadership, many businesses fail to sustain the necessary lean practices. Successful implementation and sustainability of lean practices is the focus of this work.

Lean implementation is an organisational development. Many contextual experiences and cases studies have developed the lean and organisational development literature. Some of the studies more detailed, some lacking scientific meticulousness. The organisatioknal development literature has traditionally been criticised for exaggerated contextualisation.

- There is need for further scientific rigour at the merger of lean and organisational development.

Merging the organisatioknal development and lean literature identified various aspects, and key factors for achieving the desired outcome. This progresses the study of lean success.

2.11.3 Implementation Outcomes

The review identified what true success for lean is. Often consultants are used to achieve a temporary success by applying specific tools to some processes but unfortunately, overall effectiveness is limited due to a lack of a business's actual understanding and assimilation of lean and their failure to become a learning organisation. The work defined key outcome for lean as follows.

- The key outcome from lean implementation is (1) the given performance gains with (2) sustainability of the initiative and (3) on-going continuous improvement.

This could be described as process excellence coupled with culture excellence for operational excellence.

2.11.4 Implementation Aspects

Two key schools of thought or aspects of change were identified:

- Change can be planned and episodic.
- Change can be continuous and emergent.

It is believed that lean implementation is best described as a planned change for continuous emergent change, a learning organisation (see page 135).

2.11.5 Employee Behaviours

Employees respond to changes by either accepting or resisting them. Their reaction involves both their rational decision and emotional drive for the change. Resistance can be seen as a problem with the person but most likely is a reflection of poor leadership, expressed in top down managerial pressure. Resistance could come from a lack of understanding, a lack of self-control. Else, there may be something truly wrong with the proposition and the resistance is warranted.

2.11.6 Leadership

The sustaining of the organisational change, engaging of employees and aligning their behaviours is undoubtedly a challenge for leadership. This is leadership not mere management.

Change leaders need to provide the direction, the motivation and keep the journey going.

- This involves strong commitment to the change and being a coach to support participants through the details of change.

This is opposed to a top down directive, hands-off or inappropriately delegated approach.

- It is believed leading their staff in the way they think about themselves, their identity, and role within the organisation is particularly useful.

2.11.7 Key Factors

Merging the OD and lean literature identified key factors for leadership to address. These are considered a summary of the tentative success factors for lean implementation. Specifically identified were:

- Basic literature on lean identified goal setting and review (like PDCA) with a journey view of on-going continuous improvement as key to success.

Other key factors can be summarised as:

- Setting strategy and vision and imparting it vividly to staff
- Forming positive groups including or a guiding coalition
- Developing the communication process for understanding, collaboration and alignment
- Maintaining the momentum of change
- Embedding culture, celebrating success including small wins (as opposed to large impact)
- Supporting the habits in employee environment and process (e.g. visual systems and standard work)

Additionally the review identified:

- Situational variables of business size, product mix, industry, and country or culture specific
- Internal and external resources

The concept of lean knowledge and change agent capability as factors was introduced.

2.11.8 Method Selection and Implementation Risks

The risk or threats and opportunities of implementation were reviewed in the context of decision making in lean implementation. The literature for the application of risk management to lean was reviewed. No significant applications were found.

The application of risk analysis to lean implementation was seen as complimentary to this work and this gap in the BOK was targeted for development.

2.11.9 Research Direction

The research direction was further set with progress towards the research questions. The work recognised that:

- The BOK could benefit from further contextualising key factors in a framework.

Regarding a method for research, it was recognised:

- For contextualisation, the research would benefit from industry interviews and case studies.[40]

This could be followed by:

- The development of a tentative framework for lean implementation.

Experimentation could then be used for:

- The modelling of correlational and causality for implementation success.
- Developing practitioner models to assist them with implementation.

[40] Ultimately this occurred concurrently with the literature review.

3. Purpose and Methodology

3.1 Gaps in the Literature and Practice

Since the 1990's, the understanding of lean has substantially developed. There are still significant gaps in the body of knowledge. Although many principles are set, research can further contribute to the understanding and application of lean thinking. Some of the areas identified were:

- Developing the ability of lean management to handle variability.
- Contingency, success factors for lean implementation specific to various industries and scenarios.
- The extent to which a manager's own knowledge impacts the success or failure of an implementation.
- Specifying what role consultants should play in an implementation.
- Explaining how exposure to information sources affects the success of lean in the context of a global study of SMEs.
- Addressing what affects managers' attitudes to seeking new information.
- Merging the intersection of lean and risk management (RM) literature; applying RM to lean implementation.

3.1.1 Specific Needs for New Zealand and SMEs

Specific needs to the New Zealand Industry and SMEs were identified and are summarised below. These were influenced by literature and concurrent industry case studies (p. 86). These were:

- Success factors specific to the New Zealand context (cultural, geographical, technological, economical, and other).
- Lean success factors for the specific SME context (as seen in New Zealand).
- Implementation frameworks for SMEs that are balanced, not overly tools focused.
- Investigating the apparent poor attitude of New Zealand managers' to seeking out lean knowledge.
- Managements' effect on the knowledge acquired and retained in New Zealand businesses and particularly SMEs.
- The effect of lean information sources on managements' attitude towards lean and its implementation.
- How staff attrition affects lean knowledge and implementation success in SMEs.
- The historical development of lean in New Zealand.

3.1.2 Needing Empirical Confirmation

There is a particular need for further rigor in investigating the findings within existing research (Baranek, Tan, & Byrne, 2010; Berthon, Pitt, Ewing, & Carr, 2002). Many contextual experiences and cases studies have developed the lean and organisational development literature. Some of the studies are more detailed and others lack scientific meticulousness. The organisational development literature has traditionally been criticised for exaggerated contextualisation and the lean literature is bordering this.

> A comprehensive empirical study of the factors with their interrelatedness and relative importance was not found except in broader contextual terms. The quantitative research for lean needs further development.

This is not to criticise the excellent work done but recognises there is room for quantitative empirical work. Qualitiative works do provide researchers with a rich source of contextual data, not readily available in quantitative works (Taylor, 2005). Therefore quantitative methods are prone to missing key contextual factors. However the contextual work in lean implementation is well developed. Building on contextual findings, work to quantitatively explore the specific factors, relationships, and underlying causality is desired (Marzec & Matthews, 2012; Wold, Eriksson, Trygg, & Kettaneh, 2004).

3.2 Purpose

The purpose of this work was to identify and explore lean success factors. This included the extent to which a manager's own knowledge impacts the success or failure of an implementation. This was a worthwhile exercise because of its potential to enhance productivity and the commercial success of New Zealand industries through successful lean implementations.

One of the focuses of this work was to contribute to the success of manufacturing and engineering in New Zealand. But the scope of the work stretches well beyond this context, contributing to the success of lean implementations universally.

3.3 Hypotheses

Four research hypotheses were formed. Management commitment to lean has been expressed as an overriding success factor for lean; Hypothesis 1 expressed a refinement and advancement of this. That is, leadership must understand lean and the intricacies of an implementation. This is opposed to commitment to "do lean" as a strategic objective, something the company needs to do but not involving leadership directly.

> ***Hypothesis 1: The major success and failure factor for lean is leadership knowledge.***

In the *resource based view* (Barney, 1991), knowledge is seen as the preeminent resource of a firm (Grant, 1996), hence deliberate learning (Zollo & Winter, 2002).The proposition here was that leadership's lean knowledge is the primary resource for lean implementation. This is a knowledge-based view for lean success.

Further hypotheses addressed other success factors.

> ***Hypothesis 2: Consultants and the tools or methods of lean are secondary. The primary aspects are leadership and enabling development.[41]***
>
> ***Hypothesis 3: The key success factors for lean do not differ due to business size, and product mix.***

The last hypothesis reflected specific concern for New Zealand.

> ***Hypothesis 4: New Zealand's senior managers (represented largely by those in SMEs) have been slow to pick up lean management.***

3.4 Method

Literature reviews were grounded by a contextualisation study, and then an experimental analysis was conducted. The main experimentation was composed of an opinion survey and a case-study questionnaire. The research approach developed from a critique of existing methods for lean research. The critique covered the different methods of research their benefits and detriments, including bias, ethics, and technical tools (e.g. statistical methods). A small portion of this review is included in the appendix, page 369. The developed method is below.

Although this work incorporated an early contextualisation study, the philosophy was significantly positivist, relying on scalar questionnaire data and quantitative analysis.

3.4.1 Contextualisation Study

Because of the complexity of lean implementation, contextualisation studies were incorporated into the work. This involved reviewing lean in New Zealand and practical involvement in actual lean implementation. These case studies were used to contextualise for the researcher the many facets of implementing lean change. This qualitative methodology supported the understanding developed in the literature and the distilling of conceptual frameworks. Additionally, as there was limited literature available on lean in New Zealand, the miniature qualitative study, particularly in small business lean was highly valuable. These contextualisation studies, enriched resulting models which laid the groundwork for the quantitative (positivist) work.

Lean Practice in New Zealand–Contextualisation Study

The history and contemporary practice of lean in New Zealand was reviewed. This investigation was structured around understanding the key issues, including those specific to New Zealand. There is only a small amount of research published or available on New Zealand lean. Because of this, prominent businesses and practitioners were identified with the help of internet resources, interview, and personal referrals. Personal communication by email and telephone interview was the primary source.

[41] In this work, enabling development is related to employees and their being involved, aligned, and supported.

Implementation Case Studies–Industry Embedment

The researcher embedded himself in an industry as a lead in implementing lean practice. This grounded the research in reality. He placed himself in a lean change management role in the construction industry (11 months) and then as an advisor for lean practices and support to lean technology implementation at a precision engineering SME (6 months). This was additional to previous experience as the lean team leader for a (self-confessed) poorly executed lean implementation (24 months). This initial bad experience gave impetus for gaining a better understanding of lean and led to the research topic. One case was a precision engineering job shop in a struggling industry. Another case, although still make-to-order, had a product with a relatively defined process and was in a boom industry. These cases allowed perspective of different situational factors and the practical challenges faced, particularly related to responses of staff, their resistance, and engagement. This grounded the research in reality.

3.4.2 Development of Conceptual Frameworks

The lenses approach to literature review (p. 4) allowed for division of the problem and parallel thought development. By coupling the literature outcomes with industry interviews and cases studies, many factors for lean success were identified, and tentative conceptual frameworks for lean implementation were developed (p. 134).

Selecting Factors

The critical success factors used to build the conceptual frameworks came from the lean literature merged with the established organisational change literature and outcomes of the contextualisation study.

Others have used a questionable approach, reviewing the lean literature to identify the importance of various aspects of lean implementation (see Anvari et al., 2010, 2011). The number of literature references made in regards to a given factor was used as a measure for how important a factor may be. This approach is prone to error. For example, many have viewed lean as a toolkit or set of methods; due to this, the literature tends to focus merely on what tools are the best to implement first. This biases the number of references towards a “tools and processes” category. Others have used survey and data mining techniques (rough set) to categorise factors (Shaobo, Chunhua, & Hongliang, 2009) but this again has taken a tools or technology approach.

To avoid bias, the researcher prefers investigating reliable and well tested research cases as opposed to the majority of cases. This is similar to methods used to confirm legitimacy of ancient texts (Holmes, 1983; Wallace, 1994). The contextualisation studies of industry further supported the findings of this approach.

3.4.3 Correlation and Causality Modelling

Statistical models of correlation and causality were built for lean implementation. Two web based questionnaires were developed based on the conceptual frameworks (p. 134) along with situational variables. Correlation models (including structural equation models) were developed from the data sets gathered. This was the primary hypothesis testing with causality discussed from the correlations found. The full questionnaires and ethics approvals are in the appendix, page 495. The specifics of each experiment are introduced here.

Questionnaire (Experiment) One–Lean Knowledge, Survey Investigation

The first questionnaire was a general survey focused on perceptions of lean. This survey was used to investigate lean uptake and success of implementation by analysing a diverse population. The survey addressed opinion about lean success and specifically the perspective of lean knowledge. It was hypothesised that, lean knowledge is a major success and failure factor. In order to understand this factor, the surveyed population embodied more than just avid lean practitioners but also those with moderate, little, or no knowledge of lean. Participants were encouraged to fill in the survey regardless of their own knowledge of the subject matter.

Questions were arranged as Likert scales. Initial comparisons were made by Analysis of Variance (ANOVA) and followed by exploratory factor analysis, and then partial least squares structural equation modelling (PLS-SEM). Free form text responses were tallied and tabulated.

A significant data set of **758 responses** was gathered for this survey.

Questionnaire (Experiment) Two–Implementation, Multiple Case Studies by Questionnaire

With quesionnaire One, the survey of lean knowledge as the base, questionnaire Two was used to conduct a detailed study of success factors by analysing case data. This questionnaire that focused on actual actions and outcomes of a lean implementation. Distribution targeted lean or similar practitioners who embarked on significant implementations but specifically antbody who had experienced or observed and implementation and was able to respond to the questions. It asked participants what specific actions were taken during implementations and the implementation outcomes. This questionnaire served the purpose of gathering a large amount of case study data.

The implementation questionnaire gathered data for **1253 cases** from over **44 countries**.

Longitudinal case studies have been the preferred method for analysing lean and factors for its success. These methods are helpful in eliminating some subjectivity but it is very difficult to gather a large enough data set to compare how different sectors and situations respond. For example, it would be difficult to compare:

1. High-variety low-volume manufacturing to low-variety high-volume manufacturing.
2. Small with larger manufacturing enterprises.
3. New Zealand and Australian instances of lean with other countries.

With the current maturity of lean thinking, the majority of success factors have already been identified and models developed. Based on these a carefully designed case questionnaire approach was possible. This method was able to incorporate the existing success factors into a web based questionnaire for the gathering of a significantly large data set. The data set enabled a comprehensive empirical study of the critical success factors, their relative importance, and the correlations between them; this is a seminal contribution to the body of knowledge.

Questions were typically arranged as Likert scales with some categorical questions and sufficient room for free text responses. In the data analysis, importance rankings were made by a correlation matrix (r, p, n) and two selection algorithms (F statistic and Chi Square).[42] These three outputs were tested by cross comparison and a predicting model validation (simple C&RT). Structural equation modelling (PLS-SEM) was then used to explore underlying causality. This produced many significant exploratory models of lean implementation. The freeform text responses were tallied (p. 447) and reported in the analysis where appropriate.

3.4.4 Model Integration and Discussion

The questionnaire experiments made it possible to test the hypotheses and conceptual models. This developed a better understanding of the causality for lean success. An integrated practitioner model was developed for discussion purposes and for supporting practitioner learning.

3.5 Explanation of Statistical Methods

In the analysis of questionnaire data, various statistical methods were used. Basic descriptive statistics techniques and *Pearson's r* correlations were incorporated alongside more advanced methods. Some of the techniques used are not that common in lean research. These are explained briefly below and particular attention is given to structural equation modelling.

3.5.1 Using Likert Scales

Care was taken in organising ordinal variables to provide a Likert type scales for analysis (see questionnaires, p. 509). There is debate about the reasonable use of Likert data, and particularly the assumption of equal intervals in ordinal scales. A minimum 5 point scale is recommended. Pragmatically, a particular understanding of the data and its limitations is necessary (Grace-Martin, 2008; Jacoby & Matell, 1971; Jamieson, 2004; Kampen & Swyngedouw, 2000; Knapp, 1990).

3.5.2 ANOVA—A Statistical Method for Group Comparisons

ANOVA[43] was used throughout the analysis to compare group means within a sample. The differences were displayed in means plots or tabulated with effect size 'F' and significance level 'p' where; $p < 0.05$ is

[42] The statistical methods of experiment one and two were different due to their specific requirements although methods. The first experiment was looking at differences in means by key grouping variables. So ANOVA was typically used followed by EFA and a small amount of SEM. The second experiment was more interested in how factor 'A' responded with 'B' as well as their relative importance. Therefore correlation matrices and data mining algorithms were initially used followed by extensive SEM.

[43] The concept of variance was introduced in statistical work in 1918 (Fisher, 1918), and ANOVA was presented in 1921 (Fisher, 1921). ANOVA calculates sums of square distances between each value and the mean values within and between groups.

typically borderline significant but a smaller p value is preferred for smaller effects (this is true of other methods also especially where Likert data is used). The APA (America Psychological Association) way of reporting ANOVA effects is $F(df_{effect}, df_{error})=F_{value}$, $p=p_{value}$. The F_{value} is the effect size calculated for the difference and df_{effect} is the degrees of freedom, i.e. 1 for one way ANNOVA. For those new to ANOVA, df_{error} can be thought of as the total size of the sample being analysed (=n-2 for one way case). This is helpful in understanding statistical power. See (Hill & Lewicki, 2005).

ANOVA is relatively robust to deviations from normality, e.g. it can handle a degree of skew. ANOVA typically favours accepting the null hypothesis; it needs a stronger effect size to show a significant difference between means. ANOVA is a safe method to use. See Hill et al. (2005) and references therein.

3.5.3 Variable Selection Algorithms for Importance Ranking

Variable selection methods ranked the success factors. These utilised proprietary regression algorithms to identify best predictors. These methods are somewhat heuristic (StatSoft, 2013a, 2013b). Because of this, three approaches were compared for statistical strength. The three methods were a correlation matrix (r), a proprietary F-statistic algorithm, and a proprietary chi-square algorithm. The benefit of the algorithms used was their ability to test linear and non-linear relationships (StatSoft, 2013a). The rankings were confirmed by building a prediction model (CHAID C&RT). The model was built from the ranked variables using a training data set. The resultant model was tested against a validation data set (Y. (Jett) Lee, 2013). The high accuracy of prediction confirmed that the variables included were highly significant.

3.5.4 CHAID Classification and Regression Trees

A CHAID[44] Classification and Regression Tree (CHAID C&RT) prediction model was used to validate the top ranked variables. CHAID C&RT is one of multiple algorithm methods used to build a classification tree, which is a hierarchical structure of decision rules, (Hill & Lewicki, 2005; Naftulin & Rebrova, 2010). Once the tree model was built, case data could be classified (prediction made) by cascading the data through the decision tree. This was a simple method for building a prediction models.

See Validation by Prediction Model, page 220.

3.5.5 Factor Analysis for Underlying Constructs

Exploratory Factor Analysis (EFA) was used to uncover the underlying constructs and in effect reduce dimensionality (Fabrigar, Wegener, MacCallum, & Strahan, 1999; Hill & Lewicki, 2005). The EFA algorithm used *principal axis factoring* (PAF) with *Varimax* orthogonal rotations.[45] Oblique rotation

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[44] Chi-Square Automatic Interaction Detection

[45] Rotation adjusts matrix coordinates to better align variables with the uncovered factors. Varimax, an orthogonal rotation, maximises the sum of correlations (or squared variances) between the variables and factors. Varimax is arguably the best and most common orthogonal rotation (Dunteman, 1989; Fabrigar, Wegener, MacCallum, & Strahan, 1999).

(hierarchical analysis of oblique factors)[46] was used to confirm suitability of the orthogonal approach (Fabrigar et al., 1999). Principal Components Analysis (PCA) was used for comparison and confirmation of EFA in experiment One. Strictly speaking, EFA is used to uncover the underlying constructs and PCA is used for reducing dimensionality. Although some argue that PCA serves both purposes: "The goal of common factor analysis is to explain correlations among measured variables, the goal of PCA is to account for variance in the measured variables" (Fabrigar, Wegener, MacCallum, & Strahan, 1999).

3.5.6 Path Analysis by Structural Equation Modelling

Structural Equation Modelling (SEM) is an advanced statistical method used typically for Confirmatory Factor Analysis (CFA) but also Exploratory Analysis (EA). Similar to the EFA discussed above, it incorporates underlying constructs related to measured variables, but also paths between them. An example SEM diagram is shown in Figure 12. Measured variables, the boxes in SEM diagrams, are used to form an outer measurement model; these are the indicators of the latent constructs. The latent constructs, shown as circles, typically cannot be measured by a single indicator. An example of this is trying to measure the character trait of loyalty by a single variable. Constructs can be formative (*Construct 4,* Figure 12); or reflective based on whether measures form or reflect the construct. Reflective models are used in this work, i.e. highly related variables reflected the latent constructs. Paths between constructs are given a coefficient, path coefficients are analogous to beta (β) values in a regression equation, ($y=\beta x+\varepsilon$). Constructs are typically given an R^2 value. That is the variance of the construct that has been explained through incoming paths.

SEM has become a useful technique for modelling causal relationships. As with other methods, care must be exercised in claiming causality. Although model quality validation may indicate a well-fitting model may there is still the possibility that another model may exist that fits the data just as well or better (Lei & Wu, 2007). Many publications are available on SEM such as an introduction, its practical use and the critique of its use (e.g. Lei & Wu, 2007; Hoyle, 1995; Chin, 1998a; Haenlein & Kaplan, 2004; Hill & Lewicki, 2005; Joe F. Hair, Sarstedt, Ringle, & Mena, 2012).

[46] Oblique rotations allow for correlation between factors (Fabrigar et al., 1999; Field, 2013; Hill & Lewicki, 2005).

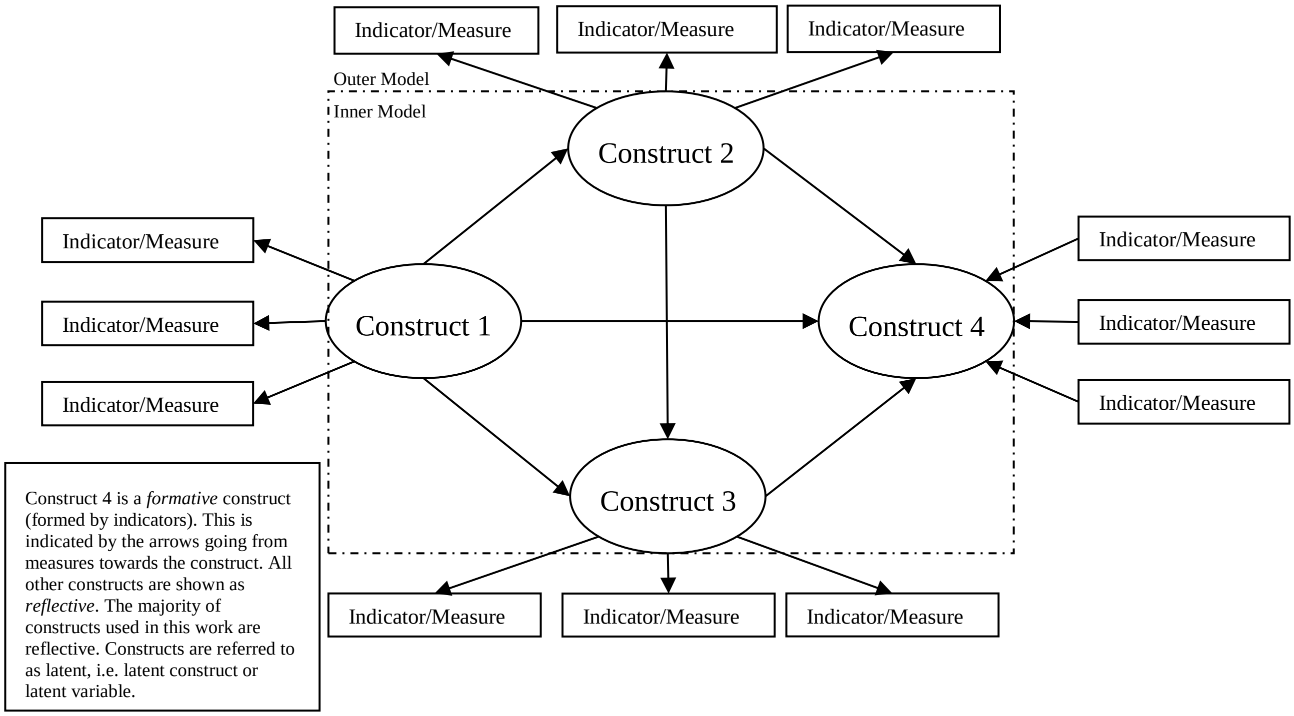

Figure 12 Example structural equation model showing measured and latent variables and paths.

3.5.7 Partial Least Squares SEM

The method of SEM used in this work was partial least squares (PLS) via SmartPLS[47] software. PLS-SEM has been put in the shadow of other SEM methods (Rigdon, 2012) and its choice warrants further discussion. Traditional SEM (e.g. LISREL) methods (Lei & Wu, 2007) are covariance-based whilst PLS-SEM is a component-based technique (Haenlein & Kaplan, 2004; Rigdon, 2012). The difference has been compared to the difference between FA and PCA (Chin, 1995). Because of the differences, covariance-based approaches have been held in more regard than component-based ones; but these two are mere alternatives for empirical approximations (Rigdon, 2012).

PLS-SEM, as any method, has its positives and negatives. Problems of component-based methods are overestimation of indicator loadings (measurement model) and underestimation of paths between latent variables (Hsu, Chen, & Hsieh, 2006; Rigdon, 2012). However, PLS-SEM is suited to both reflective and formative constructs. The ability to handle variations from normality and small sample sizes are the most common justification for its use, ~50% (Joe F. Hair et al., 2012). But reasons that relate the research objectives to the original purpose of the PLS-SEM algorithm are preferred. That is, for use in exploratory research, predictive analysis, explaining variance in latent constructs, or where theory is not well developed. Although identification issues (model accuracy and problems of improper solutions) are concerns in alternative methods, they do not constrain PLS-SEM even if models are highly complex. Also, the poor estimation of indicator loadings and paths coefficients can be reduced by increasing the number of indicators

[47] SMART PLS Version: 2.0.M3 (Ringle, Christian M., Wende, Sven, & Will, Alexander, 2005)

and the sample size; this is called consistency at large. See Hsu et al. (2006), Hair et al. (2011; 2012)[48] and Haenlein et al. (2004). The above reasoning for choosing a component-based method over a covariance-based method is summarised in Figure 13.

	Primary Reasons				Secondary Reasons	
Reasons for using a component-based SEM technique (like PLS-SEM).	If formative indicators are required.	If latent variable scores are important.	If the model purpose is for prediction.	If the model (theory) is at an early stage.	Sample size is small.	Data deviates from normality.
Reasons for using a covariance-based SEM technique (like LISREL).			If the model purpose is for theory testing	If the model (theory) is at a developed stage.		

Figure 13 SEM method selection criteria. Secondary and primary reasons for choosing component based methods (like PLS-SEM) versus co-variance based methods. (Table A. Pearce)

Lack of Theory in Lean Research

The need to test operations theory by SEM was suggested strongly in 2004 (Wold et al., 2004) but there has been little progress in lean. The original literature review for this work uncovered only one SEM article (T. A. Boyle et al., 2011). A further search for lean SEM studies found the analysis of small manufacturing firms (Vinodh & Joy, 2012; Vivek & Ravichandran, 2008), supply chain models that included supplier involvement (H. Shin, Collier, & Wilson, 2000), and relationships between lead time and information technology (Ward & Zhou, 2006). These studies were limited in size and scope. The more complex and relevant models studied the relationships between lean management, environmental management, business outcomes, and environmental outcomes (Yang, Hong, & Modi, 2011); the relationship between lean practices, non-financial performance and profit (Fullerton & Wempe, 2009); and the relationship between greening the supply chain and competitiveness (Rao & Holt, 2005). Similar use of SEM was also seen in agile manufacturing (Vázquez-Bustelo, Avella, & Fernández, 2007). More recent research has begun to address measurement scales for lean constructs (Cherry, 2012; Shah & Ward, 2007). None of these studies addressed lean change but rather the lean practices of a firm.

> Although empirical SEM studies are slowly emerging, the development of scales for defining constructs is lacking (Shah & Ward, 2007). Theory in lean, and especially lean implementation is contextually mature but not empirically developed or tested (Vinodh & Joy, 2012) to this quantitative level.

The lack of developed theory is a gap in the body of knowledge and suggests that PLS-SEM should be used in this work. In fact, the criteria for SEM method selection (Figure 13) pointed towards a component-based approach.

[48] The work of Hair et al. (2012) in reviewing usage of PLS-SEM in market research is particularly useful, providing guidelines for publication.

3.5.8 Justification for PLS-SEM in this Work

All the points below indicate a component based method is preferred for this research (see Figure 13).

- The flexibility for trial of formative indicators, although not essential,[49] was desired.
- Latent variable scores were important.
- The model purpose was exploratory and in the nature of prediction.
- The theory in this study and in the field of lean is at an early stage.

Additionally, the ability to handle non-normal data and the flexibility to investigate smaller samples (smaller slices of the data sets) was beneficial (Joe F. Hair et al., 2012; Hsu et al., 2006).

Sample size was particularly relevant to this work. It was beneficial to use small samples in the analyses, as well as take advantage of consistency at large. Although a minimum of 100 to 200 samples have been recommended for covariance based methods, much smaller data sets have proven successful in component based PLS-SEM (Haenlein & Kaplan, 2004) i.e. as low as n=20 (Henseler, Ringle, & Sinkovics, 2009). A rule of thumb is given here:

> *"PLS-SEM minimum sample size should be equal to the larger of the following: (1) ten times the largest number of formative indicators used to measure one construct or (2) ten times the largest number of structural paths directed at a particular latent construct in the structural model."*
>
> (Joe F. Hair et al., 2011; Barclay, Higgins, & Thompson, 1995)

However, the data set still needs to be considered in full. This includes looking for potential missing data, considering the psychometrics of the variables, and the magnitude of the relationships (Henseler et al., 2009).

Scale development[50] also needs special mention. Scales require careful consideration and confirmation (Cabrera-Nguyen, 2010; Worthington & Whittaker, 2006). Although the theory for scales in lean is weak, exploratory scales were developed from the current body of knowledge. Quality tests, e.g. indicator loadings and reliability, provided confidence in the adequacy of these scales for exploration with PLS-SEM.

[49] A formative construct of Womack and Jones' five principles of lean was investigated, but not incorporated in any of the final models (J. P. Womack & Jones, 1996).

[50] The specification of the specific measurements used to describe a specific construct.

4. Contextualisation Study

The main work started with a contextualisation study to ground the research in reality. This involved reviewing lean in New Zealand and being practically involved in an actual lean implementation. This study enabled an understanding of the key issues for lean implementation, contextualising lean success in New Zealand industry. This work contributed to the development of the hypotheses (see Contextualisation Study Outcomes, p. 130).

4.1 Lean in New Zealand—Contextualisation Study

4.1.1 Sources

There is little documented history of lean manufacturing in New Zealand. Because of this, the primary sources in this section are interview based. The work was relevant and contributive to knowledge of lean in New Zealand.

The interview sources, mainly telephone based, were selected from an initial investigation and discussion with Ken Gardiner (Lean Programme Manager for New Zealand Trade and Enterprise[51]), and academics readily promoting or researching lean in New Zealand; Thomas Neitzert of the Auckland University of Technology, Jane Goodyer of Massey University, and Jeff Heyl of Lincoln University. Because of Gardiner's own involvement in the field and his unpublished research, he was a useful source and helped point out other key lean players in New Zealand. Ken Gardiner directed further enquiries to Dean Joiner (NZTE Better by Design) who then led to Nigel Reaney (ex. Toyota UK and now operator of LMAC lean consultancy).

New Zealand Trade and Enterprise (NZTE) began investigating lean use in New Zealand as the groundwork for their lean programme. At that time, (2004) NZTE found very little saturation of lean knowledge. There were only a couple of consultants identified as offering lean-based system support or implementation. A survey of 25 manufacturing companies found 24 had no knowledge of lean. One company thought they understood lean and had productivity sorted but didn't need lean—this was highly questionable. There was no available institutional learning provided in lean.[52] In the late 1980's there had been an emergence of lean thinking on the world stage with the translation of Taiichi Ohno's book, the *Toyota Production System* (Ohno, 1988), the publishing of the MIT work and in particular *The Machine that Changed the World* (J. P. Womack et al., 1990). But in 2004, reasonably late in the development of lean thinking, New Zealand had not grasped these developments. New Zealand's typically lethargic response to current business thinking is

[51] During the course of this work, Ken Gardiner moved into another role at NZTE and the programme was transferred to Callaghan Innovation.

[52] Personally the author recalls only the concept of JIT covered in his undergraduate mechanical engineering degree (2002-2004). He did not recall being taught lean as a system, but rather the opposing concept of economies of scale.

considered by practitioners as a factor in its limited saturation. New Zealand seemed to miss the lean wave in the 1990's nearly entirely (Gardiner, 2011; Joiner, 2011; Reaney, 2011). Earlier research from the University of Waikato agreed with this but indicated knowledge was on the rise; see Basnet et al. (2006).

There were only a few early lean adopters in New Zealand. These have been identified primarily as the Toyota Thames Plant and Fisher & Paykel, but closely followed by the likes of Fonterra and Laminex (Gardiner, 2011; Joiner, 2011; Neitzert, 2011). By 2004 banks had also began to introduce lean and were practicing its concepts, but there had been very little audience for these early players and little saturation of the knowledge of lean thinking in New Zealand.[53] This lack of lean knowledge saturation was revealed by the previously mentioned NZTE research in 2004 (Gardiner, 2011).

Among the few early adopters of lean, the Toyota Thames Plant and Fisher & Paykel exemplified New Zealand's successful implementation; there was the application of the lean concepts in these New Zealand businesses at an early stage, that is pre the publishing of *The Machine that Changed the World* (J. P. Womack et al., 1990). The Toyota Thames Plant developed their own version of the Toyota Production System; they are clear examples of a successful New Zealand implementation. Fisher & Paykel pioneered flexible manufacturing and JIT in the whiteware industry through firstly kiwi[54] ingenuity and secondly benchmarking by observation of Japanese plants. Because these are clear examples or cases of lean adoption in the New Zealand businesses, further details of these two cases are included below. Particular emphasis is given to Fisher & Paykel; their initial discovery of key lean principles had no direct link with Toyota, as Toyota Thames had.

4.1.2 Toyota in New Zealand, the Toyota Thames Plant

The Toyota Thames assembly plant may have been one of the most influential players in early lean adoption in New Zealand (Gardiner, 2011; Neitzert, 2011). The Toyota assembly "transplant" was initiated in Thames, New Zealand in 1969[55] (Toyota, 2010) when Campbell Industries Thames began to assemble Toyota Coronas. Toyota Thames influenced New Zealand with lean in a similar way as Toyota's assembly operations affected the American industry, exposing it to the TPS (Holweg, 2007; J. P. Womack et al., 1990). However, the difference was that the Toyota assembly plant in Thames developed their TPS systems much on their own (Gardiner, 2011).

The Thames plant was setup with the same purpose as Toyota transplant operations elsewhere; to circumvent the trade restrictions on vehicle imports. However, this New Zealand plant, supplying a small population, was significantly smaller and of less significance to Toyota than the previously mentioned American

[53] It has been indicated that there was some relatively early lean practice at the NZ Post (possibly late 80's) and by the same people there is some exciting service industry based lean thinking taking place in the Christchurch District Health Board Business Development Unit. It is intended to investigate this and other sources as part of further work.

[54] A person from New Zealand.

[55] The Toyota Thames plant produced its last car in 1998 but continues to operate as a used vehicle service centre (Toyota, 2011).

transplants. Because of this, the Thames plant received very limited support in implementing the TPS. This forced the Thames team to develop their own version of the TPS based on their own research. The Thames team was able to visit the Japanese Toyota sites but the aid extended little further than this. Toyota Thames developed their own TPS manuals for what you could call the Toyota Thames Way. The parent company, Toyota Japan was impressed in what they achieved in the New Zealand based system (Gardiner, 2011).

Training Within Industries (TWI) was instrumental in the Toyota Thames implementation (NZ Archives, 2010; Warren, 2012b). It appears they lead the way in application of TWI outside of Toyota. John Shook (Toyota's first American employee and LEI president) is quoted:

> *"In 1985 or so, the senior manager and training manager of Toyota's New Zealand operations spent about a week with us in Toyota City during which time we compared notes on TWI. The New Zealanders were the only Toyota global organization I met that had experience with TWI outside of Toyota's direct influence."*
>
> John Shook *(Warren, 2012b)*

TWI was supported by the New Zealand government's Industry Training Services. TWI made good progress in NZ but was ultimately disestablished in 1987 (NZ Archives, 2010; Warren, 2012a).

The Toyota Thames assembly plant is a good example case for a successful New Zealand implementation of lean TPS principles.

4.1.3 Fisher & Paykel's Lean Journey

Fisher and Paykel's history in lean manufacturing is a longitudinal study of lean implementation in New Zealand. It is beneficial to consider this case in some detail.

Starting with sales of whiteware[56] in 1934 Fisher and Paykel began to manufacture other company's products under licence when import and trade restrictions came into force in 1938. The company's labour force was protected by the government through the war and consequently the company was able to grow and expand. To truly achieve financial success they set about to manufacture their own product line with innovative points of difference. That was the late 1950's, in the late 1960's the company began to export these whiteware products (AUT Business, 2011; Fisher & Paykel, 2011).

> *"Selling to countries, such as Australia, Hong Kong, Singapore, and Japan annual export income rose from $500,000 to $2.4m between 1967 and 1971. At the same time, planning began for a new factory at East Tamaki (13,684 sq m), with twice the production capacity of Mt Wellington."*
>
> (AUT Business, 2011)

[56] Household appliances such as fridge-freezers, washing machines, dryers. In addition to whiteware Fisher & Paykel also set up a health care division (AUT Business, 2011; Fisher & Paykel, 2011).

It was a great breakthrough for a New Zealand manufacturing company to be successful in supplying to overseas markets (Joiner, 2011). Though they were generating large production quantities by New Zealand standards, Fisher & Paykel (F&P) did not possess the scale of production like their relatively giant American competition.

The quantities of production runs at Fisher & Paykel were considerably smaller than their American competition. Therefore, the conventional automated production machinery was not suited to the parameters of operation for this New Zealand manufacture. Their machinery needed to suit shorter product runs by having quick changeovers between products. Fisher & Paykel thus became a true pioneer of New Zealand based lean thinking. This was not primarily by assimilating and adapting the Toyota Production System but by applying innovative thinking to engineer solutions to the challenges of the local environmental. This resulted in Fisher & Paykel stumbling on, and *pioneering flexible manufacturing systems* in the whiteware world as early as 1972.

When Fisher & Paykel manager Dean Joiner began with the company in 1972, he was in his early 20's. At that time, the manufacturing plant had a sheet-metal shell-line. In that line was a roll-former that had a 2.5 second changeover between product types. The similar lines in America had a four hour change over. The line was built by Ward Engineering and utilised single transistor based electronic control. The flexibility of this machine was required because, economically Fisher and Paykel couldn't afford to have a different line for each product; and to keep up with demand they needed the line running at near full capacity. At the time, there was great demand for the F&P and Kelvinator chest freezers. Fisher and Paykel needed flexible manufacturing with quick changeover to be both economically viable and to supply the demand. These lean principles were being practiced in 1972 as confirmed by Joiner (2011).

In addition to the quick changeovers, Fisher & Paykel also pioneered the use of pre-painted sheet-metal. Fisher and Paykel were manufacturing Panasonic products under licence using pre-painted panels. Pre-paint eliminated post-painting, a time consuming bottleneck in their production. Panasonic had realised the future was with the pre-paint process and Fisher & Paykel applied the same thinking to their products. Blemish free pre-painted steel supply was an important part of this improvement and *they needed to work closely with their suppliers*. New Zealand steel manufacturers could not master the process and thus Fisher & Paykel eventually had to use NKK and Kawasaki steel mills in Japan. In 1972 Fisher & Paykel were producing the world's first pre-painted clothes dryer and in 1979 a compact line of refrigerators came out and is still in production today.

The above mentioned process improvements were achievements in their own, right however the hidden achievement was that *these improvements would make just-in-time manufacture (JIT) possible*. Dean Joiner was made the manager of the Fisher & Paykel Refrigerator Division in 1979. By 1984, Dean's team was ready to turn the refrigerator plant into a full automated line (sheet-metal only). Early waves of visits to Japan were occurring (Schonberger, 2007) and Joiner took part. Joiner visited Japan in a team of four including two union heads.[57] They embarked upon a three week Masaaki Imai[58] tour which included some *"mind blowing automation"* (Joiner, 2011) e.g. at the Panasonic plant. There was a lot for these four from small scale New Zealand to get their heads around. The team visited Toyota and Nissan factories and their suppliers e.g. NKK spark plugs and Kamatsu. However, the most defining moment occurred when Joiner attached himself to a tour of the Toyota Corolla plant in Toyota city, east of Nagoya. The entire plant operated in unison like an *"orchestra playing"* (Joiner, 2011) and Corollas rolled off the line every 30 seconds. Small trucks were arriving carrying parts and assemblies, e.g. engines, from nearby suppliers for just-in-time manufacture. Radio communication was used to ensure these assembly components were arriving as scheduled. Joiner's eureka moment was had when he realised that the transaxles coming off the small trucks were of different types and not batches of the same type. The Corollas rolling off the production line were different models. Joiner discovered what the key of just-in-time was to him—"*every model - every day - one at a time"* (Joiner, 2011). Joiner then related this to their own factory and the upcoming install of automated refrigerator production lines. He realised that because they had moved away from the complicated paint process, which necessitated long setups, Fisher & Paykel could feasibly do with whiteware what Toyota had with automobiles.

In 1985, Fisher & Paykel began manufacturing refrigerators in a batch size of one. One piece flow was achieved. This was unique in the appliance world. At the time, they didn't realise the need of advance production management systems, so the first year was wrought with difficulty; though through persistence they got the system running. Fisher & Paykel were manufacturing 800 refrigerators a day from a library of 1000 different models, 400 different models a day. It is *"enormously difficult to get that kind of complexity off the ground, once you have though every day is the same"* (Joiner, 2011). Fisher & Paykel had their own vehicles doing milk runs (rounds of suppliers). The trucks travelled the same route every day; picking up goods for the day's production and dropping off orders for the next day. The goods were not pushed here and there for delivery, but planned for and pulled for by real orders. By 1990, Fisher & Paykel had this kind of sophisticated and world leading plant in New Zealand and Australia (Joiner, 2011).

In 1990 Fisher & Paykel were *"doing things right"*, using efficient JIT manufacture with one piece flow. The problem is they were not *"doing the right things"* (Drucker, 2006; Joiner, 2011). The battle for market share was being fought on price. To develop a point of difference Fisher & Paykel had to revisit the importance of creating value (Joiner, 2011; J. P. Womack & Jones, 2003). Fisher & Paykel thus differentiated themselves again through design, just as they had 30 years earlier (AUT Business, 2011). Fisher & Paykel succeeded in differentiating themselves from their competitors with new products like the F&P dish-drawers; as well as custom options such as stainless steel shells, glass drawers and expensive

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[57] This people side of the Fisher & Paykel lean journey, which is alluded to here, is discussed in later paragraphs.

[58] "Masaaki Imai is the Founder of the KAIZEN Institute (KI), which was established in Switzerland in (1985) to help companies introduce KAIZEN® concepts, systems, and tools." (Kaizen Institute, 2011) - See also Masaaki Imai's book Kaizen (Imai, 1986)

handles to name a few. This naturally put more strain on the production system with estimates of around 3000 models that were now in production. However the broadened range had put Fisher & Paykel into a niche market, they were not only doing things right, but also doing the right things (Joiner, 2011; AUT Business, 2011).

It is helpful to consider the above discourse in light of the key elements of lean thinking i.e. defining value, mapping the value stream, achieving flow, implementing a pull system and continuously improving towards perfection (J. P. Womack & Jones, 2003). The bettering of themselves by *improved design* implies *creating their value proposition*, given they determined the need in the market correctly. Although mapping their value stream was not a tool they would have had available, the history shows that the entire value stream was considered, as in the suppliers of pre-paint sheet-metal and milk rounds. Flow and pull were achieved with single flexible machinery lines of one-piece flow. The goal was not status quo but a form of perfection; which brings with it another key point, empowerment of people. To reach perfection one must reduce wasteful action. This requires continuous improvement at the front-line and thus the people on the front-line need empowering. Although not seen on the surface in the above discourse this was a key characteristic in the Fisher & Paykel journey, the respect for people.

Behind the scenes of the lean-system development, there was the care for personnel. In 1979, the company was riddled with union problems. The company worked actively to switch peoples thinking and install a relationship of trust between management and the workers. Fisher & Paykel were so advanced in valuing their staff that in 1984 two of the union heads accompanied Dean Joiner on his Japan, Masaaki Imai tour. This was an early trip for Imai and accompanying the New Zealand team was the board of Philips; they were impressed with the foresight from Fisher & Paykel's management to send union members on such a tour. In 1989, learning from Japan, Fisher & Paykel started so called *mini companies* where the team leaders were the general managers and had the right to make changes within their sphere of *business*. Employees were empowered to make change, but could call on higher management for assistance. This kind of regard for staff was rare in New Zealand in the 1980's and unfortunately still is in most New Zealand manufacturers today (Joiner, 2011). Problems of leadership were highlighted by Donald Rowlands, managing director of Fisher & Paykel from 1979 -1989. He said:

> *"The reason we are in the position we are in is the stupidity of managers over the last 300 years since the industrial revolution."*
>
> Donald Rowlands as quoted by Joiner (2011)

An example of the management support (from Donald Rowlands) is Dean Joiner's being empowered to make change, empower his staff, and travel to seek out new technology and processes, rather than be happy with status quo. Another example of their seeking perfection and engaging in up-to-date business thinking is Fisher & Paykel themselves endeavoured to set up the Deming Institute in New Zealand, bringing Deming to New Zealand. Sadly, this initiative did not see fruition due to lack of interest in the country (Joiner, 2011).

This was a missed learning opportunity for a nation which is proud of innovation but is seemingly slow to respond to advancements of this kind.

Dean Joiner, after leaving Fisher & Paykel in 1999 and working abroad 5 years for Carrier Air-conditioning[59] in Saudi Arabia, returned to New Zealand in 2005. Dean was horrified; although there was a call for productivity but nearly no lean thinking in New Zealand at all (Joiner, 2011). This aside, Fisher & Paykel clearly illustrates that New Zealand implementation of lean is practicable and logical.

Apart from their observations in Japan, *Fisher & Paykel arrived at lean by applying innovative thinking to their environmental challenges whilst also opening to advancements on the world stage*. Note that no books on lean or TPS made it into their hands until 1990. *The Machine that Changed the World* (J. P. Womack et al., 1990) and any diagrams they saw in Japan were (to state the obvious) in Japanese. Fisher and Paykel is a case of what is possible to achieve in the New Zealand setting given the application of innovative thinking. This is not entirely different from the way Ohno came to develop the TPS in Japan. Dean Joiner's testimony seemed to point to an advanced thinking in the management of Fisher & Paykel, to support its staff and strive for excellence—it enabled the discovery of lean before lean.

4.1.4 The Role of New Zealand Trade and Enterprise

Although lean had proved successful in New Zealand, there was little saturation of lean knowledge until the New Zealand Trade and Enterprise's active involvement. Due to the 2005 world expo in Aichi Japan, the government was looking for projects to build bridges between New Zealand and Japan (Gardiner, 2011). NZTE (Ken Gardiner) had knowledge of the Japanese based Toyota Production System and its success. They also recognised New Zealand's need to address productivity issues in order to compete successfully overseas.

The Aichi Leveraging Fund was used to launch a pilot for a government funded lean programme. In 2004, NZTE began the pilot with 3 years of funding. From those they already worked with, NZTE identified 25 companies that had high export growth potential. Of these 25 companies, ten companies showed interest and four committed to the program. NZTE initiated the programme in these four companies with the support of a consultant. This included visits to Japan to see lean principles in use. Following the success[60] of the pilot, the Aichi Lean Programme funding was secured for a mainstreamed Direct Lean Programme in 2008. This programme includes a two day course in lean thinking coupled with change management and $20,000 of

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[59] It is interesting to note Dean's continued learning on the personal side after leaving F & P. Dean worked in Saudi Arabia for Carrier/Electrolux at their air-conditioning manufacturing plant which had 800 personal and NZD 200 million turnover. He found that culture was not a problem in the implementation of lean. Dean observed that as long as he treated people with respect he got the same results.

[60] There has been some initial studies on the success of the NZTE program (Goodyer, Murti, Grigg, & Shekar, 2011; Murti, 2009). The views in those studies, although accurate, could be taken as negative. However in reality they may have just showed the infancy of lean in New Zealand. Companies in these studies continued to advance in their application and assimilation of lean (Gardiner, 2011).

support towards a lean consultant.[61] Over 45 courses have been conducted, with approximately 1000 participants[62] representing 270 companies. 170 of these companies have taken the program with consultant funding. Other companies (15-20) have continued without the funding by opting to employ permanent staff for assisting lean implementation.

In 2011, The NZTE lean programme managers were looking at the future of the program and the assimilation of lean thinking in New Zealand business. The aim was to create in New Zealand an infrastructure around productivity improvement. From 2011, NZTE was focusing more on implementing the programme in the service industry. Because of the ties in government agencies, local government had already seen lean implementation and the benefits. Lean business clusters have been and continue to be developed around the country. NZTE also were encouraging education institutions to provide courses and qualifications[63] i.e. those education institutions would work closer with industry to provide the productivity training needed.

Along with the NZTE developed programme, the Department of Labour has built a complementary one, the High Performance Working Initiative (HPWI).[64] Additionally Competenz[65] has a competitive manufacturing programme. The Competenz program gives opportunity for staff to gain qualifications by participating in lean based courses. These initiatives are all examples of the developing lean infrastructure. The aim was that significant traction would be gained for lean in New Zealand. An example of this beginning is that the Association of Manufacturing Excellence was looking to start a chapter in New Zealand. Once Lean's benefits are more recognisable locally, businesses themselves are expected to take the initiative to employ consultants and implement lean thinking i.e. without the need for the funding and support incentive.

The NZTE programme, Better by Lean, was handed over to Callaghan Innovation in June 2013. The programme is advertised to carry out its previous functions but there are concerns regarding its future maintenance and development. These concerns stem from three sources; the infancy of Callaghan Innovation, some early critiques of Callaghan Innovation and their apparent high focus on technology development which would favour a tools approach (Callaghan Innovation, 2014; Kerr, 2013; Smellie, 2013).

The above text was confirmed by Gardiner (2011), also see MED (2010) and others (Goodyer et al., 2011; Murti, 2009; M. Wilson et al., 2008).

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[61] There are now 17 consultants on NZTE's records, quite an increase from the three of 2004.

[62] NZTE ensure that the company's management participate in the courses. This was an attempt to ensure that any resultant lean initiatives were supported from the organisations leadership.

[63] AUT introduced a diploma but it was withdrawn.

[64] http://www.dol.govt.nz/er/bestpractice/hpwi

[65] http://www.competenz.org.nz

4.1.5 Adoption in New Zealand

Lean and various other methods have been adopted in New Zealand manufacturing. Using an employment job search as a research tool shows a relatively low emphasis on TOC and Agile in New Zealand manufacturing, although Agile Software development thinking is prevalent. Searching on Seek (www.seek.co.nz)[66] for *TOC* or *Theory of Constraints* returned no relevant job opportunities where as *TQM* returned three relevant, *TPM*[67] four, "*six sigma"* 19, and *lean* returned 68 relevant job opportunities. *Lean "six sigma"* indicating hybrid lean six sigma implementations returned 11 job vacancies. An outstanding number of opportunities were for *Agile* 843 responses. Due to the share number of *Agile* hits all responses were not reviewed however these responses were scanned and deemed to be in the order of 80% or more relevant. Searching under *Information & Communication Technology* revealed that 835 of these agile jobs came from that category. Searching for *Agile* under *Manufacturing, Transport & Logistics* returned no results and under *Engineering* gave reference to Information Technology focused positions. It is recognised that there is scope for bias in this method of analysis however; it is a strong indicator of particular paradigms popularity.

4.1.6 Lean in New Zealand - Outcomes

The investigation into lean practice in New Zealand contextualised the key issues for success, as well as contributing to documentation of lean history. A key implication was:

- The uptake of lean was slow with little penetration of lean knowledge (indicating management lethargy) until the start of the NZTE program.

Even now it is unclear how many of the managers that take the NZTE courses really connect with and commit to true lean. The future of the Better by Lean Programme, now run by Callaghan Innovation, is also uncertain.

It was notable that:

- Prior successful cases did exist in New Zealand. Toyota Thames and Fisher & Paykel both adapted their own version of lean successfully.
- The respect for people principle was developed as a key issue at Toyota Thames and Fisher & Paykel.

Reviewing these companies, and particularly Fisher & Paykel, showed a level of innovation required for implementation as well as necessary support from management. It is believed less individual innovation is required when the knowledge can be provided by others study and experience. Fisher & Paykel struggled to

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[66] Search conducted on the 12th November 2011.

[67] Total Productive Maintenance is a tool of lean developed particularly in the TPS. Its purpose is to eliminate defects, unscheduled equipment downtime and accidents. This is one of the tasks of an empowered worker in the TPS. Rather than maintenance being left as the job of specific engineers, the employees are trained in maintenance techniques.

implement with inadequate lean education, having to develop their own systems. Mistakes or delays could have been avoided with further support. The work showed, at least in a limited way, that lean has proven to be beneficial in New Zealand businesses.

These insights were developed and incorporated in the research hypotheses. These hypotheses are discussed at the end of this chapter.

4.2 Implementation Case Studies—Industry Embedment

The researcher embedded himself in industry for 18 months with lead roles in implementing lean practice which grounded the research in reality. This was additional to previous experience (~24 months) as the team leader for a (self-confessed) poorly executed lean implementation (due to lack of knowledge, experience, and training). These cases allowed good perspective of different situational factors and the practical challenges faced particularly related to responses of staff, their resistance, and engagement. The actual identity of the businesses is withheld although key aspects of their operation, industry, and product type are identified.

4.2.1 Case A—Company A

Case A was for 24 months in a precision engineering jobbing shop in a struggling industry. Jobs were highly technical and employees highly skilled, but the company was struggling in the declining economic conditions. The company had a flat structure of approximately 20 staff.

The characteristic of Case A, in hindsight, was defined as implementing lean without lean knowledge. The implementation exhibited inappropriate delegation of lean leadership. It was observed that lean failed to sustain due to lack of proper focus on aspects of true lean. <u>This was not a reflection of management capability, desire, and effort.</u> Management was highly capable and dedicated to advancing the business. It is believed the lack of focus came from a poor understanding of what it is and takes to implement lean.

Company A had positioned itself well in the market place, obtained highly skilled staff, and acquired extensive plant. Still the management recognised gains needed to be made in productivity. Lean was identified as a way of improving this.

Lean was pushed to senior staff to implement without the knowledge or resources to execute it. The author, an employee at that time, was in a manufacturing administration position which included planning and procurement. He was also made the lean implementation leader. The semi-formal appointment was made after attending the two day NZTE lean course. The appointment recognised past contributions to the company systems and aptitude for continuous improvement. Later this was recognised as an inappropriate delegation of leadership. Although skills were there to improve process, there was not the education in true lean to understand what really needed to be done and particularly in the area of staff engagement. The company did begin by sending key team members to the NZTE two day course and followed with a series of lean videos[68] for education of all staff. The education, and engagement stopped after that and initial employee resistance to a new “method” became disgust. Talks of improvement didn’t seem to mount to anything and lean was proven in many of their minds to be just another management fad. Time and resources were not provided to plan or make improvements.

Management were observed to use lean as a push from the top rather than pulling improvement from the floor. There was not provision of education or the time to carry out initiatives. Key principles of lean were being compromised. It seemed management did this without even realising. Management desired process improvement but didn’t stop long to develop the human aptitude for that.

It is believed the implementation needs to be driven from the top, not a hands-off approach, because the detail is where the support and drive of leadership is needed. In this case, key lean principles were being broken by management. The manager at Company A had a long career in manufacturing. It seemed because of prior experience, and possibly hearsay knowledge regarding lean (early in lean’s development). The management team may have thought they had adequate understanding already and pursued process improvement without following true sustainable lean principles. A report based on this case proposed that management needed a *leap of faith* to *true lean* in order to overcome the existing mindset. The existing mindset is discussed below.

Management Measures Against Lean Principles

The way management measured or required operationally did not match key lean principles. These observations came from working within the business and various discussions with staff. There were repeated themes summarised below as “make the month”, “office efficiency is second to the factory”, “don’t stop the factory”, “don’t say no”, and “marketing makes the profit”. These themes violated key principles of lean and related systems thinking (e.g. TOC), disturbing flow, and creating unevenness, severely effecting productivity, and profitability. As a consequence, productivity and its relationship to staff morale is addressed.

Make the Month!

Management pressured staff to meet month end targets. This resulted in expediting all jobs that could possibly be completed by the end of month. This expediting exaggerated the unevenness of work flow resulting in decreased productivity and therefore profitability.

“Make the month” refers is a classic problem; at Company A it damaged the establishment of lean principles (including flow accounting). The “make the month” philosophy is common in public companies (Cunningham & Fiume, 2003; Darlington & Jones, 2010). In public companies, there is regular pressure to reach monthly sales targets and maintain share price. At Company A, the drivers for “make the month” are

[68] A series of videos by the Society of Manufacturing Engineers

more related to maintaining cash flow in tough trading conditions.[69,70] Regardless of why this philosophy exists, it needs revaluation and serious moderation or elimination, as it seriously decreases profitability.

Some amount of work load variation is expected within a business like this. Nonetheless, extreme variability should be avoided where possible. The "make the month" philosophy exaggerated variation through expediting. Existing plans and processes were changed; jobs were rushed and inadequately prepared for. This affected efficiencies and flow both in the office and on the factory floor. There was an increased level of stress on staff along with staff frustration at the inefficiencies introduced. The effect on staff was serious, negative impacts were seen in staff morale, satisfaction, individual productivity and ultimately staff retention.

The monthly expediting cycles exhibited themselves the first and last week of the month. The effect of this on productivity, errors (in the office and factory) and staff morale is represented in Figure 14. Based on a four week month, the chart indicates that half the month (i.e. week 1 and 4) was spent performing tasks at low productivity. The implication is that half the year or more was spent in a state of extremely low productivity and staff morale remained low throughout the year. Besides the immediate effect on productivity, the consistently low staff morale meant their productivity never reached its full potential.

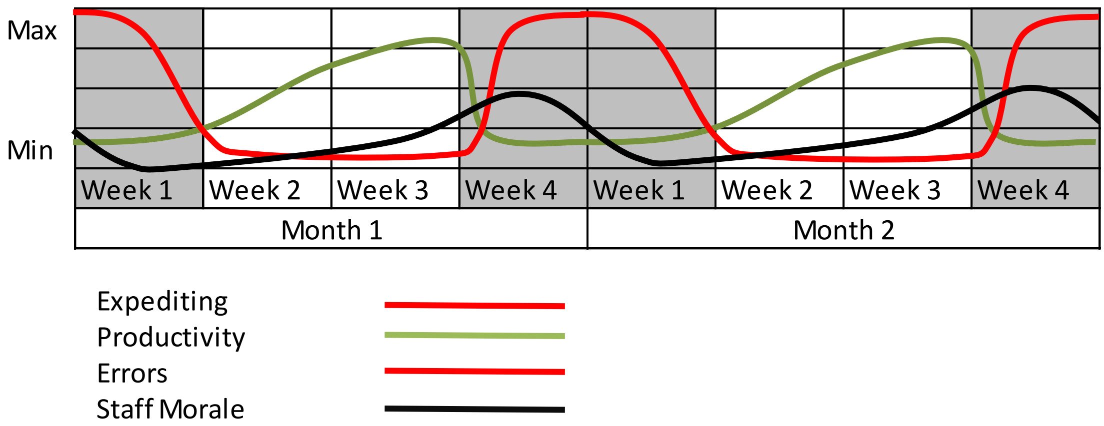

Figure 14 Observed effect of monthly expediting cycles, "make the month" philosophy: on productivity, errors, and staff morale. (Image: A. Pearce)

It is preferred to see every day as the same, maximising each day or weeks potential. With this approach, the first month of sales will be slightly lower, but ultimately average cash flows will be maintained. Eventually, as productivity increases, profitability and cash on hand will increase and stabilise.

Office Efficiency is Second to the Factor, the Factory that is Where the Money is Made.

Management took the perspective that office efficiency was second to the factory because the factory is where goods were transformed that could be sold for profit. This was reinforced as the factory was seen as

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[69] Customers frequently also gave month end delivery requirements.

[70] Possibly the "make the month" drive is also seen as a way to increase labour pace. If this was the case alternative motivation should have been pursued.

significant value proposition to the customer. However, the office was a bottle neck and huge source of waste. In the office, one contract engineer could hold up three tradesmen or make three tradesmen incredibly inefficient. This point was also observed in the theme “Don’t Stop the Factory!”

Don’t Stop the Factory!

Management took all possible steps to keep the factory busy. When a staff member was low on work, the contract engineers (CEs) were pushed to expedite work to keep them busy. This resulted in severe inefficiencies. Decisions were being made too quickly and the lack of planning created inefficiencies. Additionally shortcutting the system for expediting meant relatively simple tasks took hours to correct. Further, the CEs were a bottle neck and the momentary efficiencies they gained on the floor put them further behind. This affected their ability to support the factory floor. The CEs never got ahead but maintained a state of constant stress without making wins in planning and job profitability. Besides this, if everyone is being made busy all the time there is no time for them to develop or implement improvements. Neither the staff members on the floor nor the CEs had any time to work on improvements to increase productivity. Morale also suffered.

This illustrates how waste is created by trying to keep every individual occupied; “a plant in which everyone is working all the time is very inefficient” (Goldratt & Cox, 1984). This is easier to understand than implement; takes some knowledge to develop the wisdom and vision for a leap of faith to lean.

Don’t Say No!

Company A set out to please the customer by always saying “yes” and not “no”. There was a fear of losing customers by not accepting their requests. This had similar effects to other expediting. It affected the flow, productivity levels and staff morale.

Marketing Makes the Profit!

The attitude that marketing made the profit emphasised a high focus on sales over productivity. Company A was well developed in marketing relative to both its competition and compared to the rest of its operation. Comparatively their productivity was significantly behind. Bringing in more sales was adding to the gross sales making. However, the profitability of the sales was questionable, even though the factory was typically at full capacity, with small lulls in WIP. Adequate profit was not being made on the existing sales. The striving to increase sales, including not saying “no” to customers, meant the employees were stressed and very inefficient.

It is pointless to stress the factory if profit is not being made on the existing sales. Yes, it is agreed no sales no business, but unless the sales are profitable, having more sales is useless. It has been said that *productivity=wealth* (Cunningham & Fiume, 2003). Times were tough and these are difficult decisions to make, but the marketing arm was developed and focus could have been shifted to productivity. The proposal here is that once a base level of sales is coming in the focus should be on productivity. This is because productivity = more capacity, shorter lead times and being able to deliver promises; this then generates more sales, so productivity = wealth.

Productivity and Morale

Morale has been mentioned in the above points. The expediting and various stresses caused staff morale to suffer. From discussions with employees, it was observed that some suffered when the company changed from a very small team of approximately 5 staff to a team of around 18. When the team was smaller, there was much more interaction and involvement of management with team members and a feeling of family. The employees had much more morale and willingness to work harder, were in general happier, and were more effective. Productivity and morale seemed very much interrelated both with general staff attitude and commitment as well as their bringing forth of suggestions for continuous improvement.

Case A Outcomes

This initial attempt at lean by Company A became like a classic New Zealand failed implementation (Goodyer et al., 2011). It can be summarised as:

- Good intentions but lacking the due diligence required from management to understand and implement true lean.

At Company A, this was under the guise of gradually seeking a local solution “The Company A Way”. This is not the fault of “commitment” in the sense of desiring to be better but of acknowledging what to commit to. Again:

- Rather than having regularity and focus on staff development and improvement there was a fragmented approach to “implementing lean” with practically non-existent follow up and no consistent action with staff.

Staff meetings occurred monthly but the content was not vision inspiring and giving practical steps to the staff but the reporting of financial ratios. And:

- Financial constraints typically reinforced a short term view without long term performance gains i.e. excellent culture driving high performance and continuous improvement.

Management barely made it past process stages and the initial good start with lean videos and staff involvement fell flat. Unfortunately, “The Company A Way” had become a joke amongst staff and lean “proven” by them to be another fad. Whether trumpeting “The Company A Way” should be dropped is questioned.

The assessment was that Company A needed the pursuit of tried and proven operational excellence through true lean. This is centred on training and empowerment of staff in amongst the application of lean principles and processes. The below statement describes and observation of a culturally and operationally excellent firm:

"…these team leaders (in their words) were not, ultimately, solving problems—but developing problem solvers. And they did so not through blind trust, or by giving orders, or fixing defects: they did so through a mindful presence at the gemba [e.g. factory floor] which developed the skills and capabilities of their team."

(Shook, 2012)

It was suggested to management that as opportunities arise (e.g. lulls in work) time be taken for improvement activities but the common themes are trumpeted: make the month, don't stop the factory, and a focus on marketing over productivity. Unfortunately, with all the positive things about the firm, it is believed this attitude inhibited developing a lean business system and profitability by staying with existing practices.

- The management needed a "leap of faith" to lean, to break out of the old habits that were hindering performance and the ability to get ahead.
- It is believed that (with the benefit of hindsight) if lead staff had been allowed the time to explore the current lean thinking, or the managers themselves had developed up-to-date knowledge, immediate success would have been possible.
- It is also of note there was little particular support given to the company as an SME and make-to-order business. The NZTE enterprise course had little advice except to ignore takt time.[71]

These insights were developed and incorporated in the research hypotheses discussed at the end of this chapter. Additionally as a participant, the researcher was motivated to investigate success factors for lean.

Company A, Positive Lean Revival

Company A revived its lean attitude a year later. Various changes with factory staff occurred with a result that there was more positive staff contribution. The manufacturing manager moved from the office to be seated in the factory; this supported the culture in the factory by his active presence. Regular improvement meetings were held with particular section. That section made positive improvements including key staff changes.

4.2.2 Case B—Company B

Case B was a lean change management role in the construction industry for 11 months. The company manufactured customised products for building projects. This role was selected for its alignment with the thesis topic and ability to ground the researcher in more real world experience.

The approach to case B differed from A. The results below show that the change agent (the author) focused on developing lean knowledge first. In hindsight, this allowed for a much more successful outcome with consistent improvements being made. Problems with this implementation are also discussed.

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[71] This in effect points to a tool application not to lean principles applicable to SMEs. An alternative view would be to really help the SME to see the principle of takt as applied to flow and the heartbeat of an organization not just a production line application of takt.

There were some major points of comparison between Company A and B. Both were make-to-order businesses with ~20 staff; however, Company B did have a more standardised product and process.[72] In Company A, it appeared that management, though they had understood lean to a basic extent, delegated responsibility to an intermediate level without providing active support. They also made decisions that violated lean principles. Company B was in effect *getting the knowledge* by enlisting the help of an expert. They recognised they did not have the knowledge and understand productivity so handed this over to someone they considered an expert. The expert (the researcher) was given time to study the business; learn manufacturing strategy, and the ability to influence the company's direction. Company B did have better cash flow tan A, but the effect of cash flow on management attitudes was difficult to discern. Although company B had better cash flow, the manager (owner-operator) was more concerned about financial balance than company A. Still, this could have influenced the ability to make change through releasing resources. Company B was in industry that had a slight resurgence and was looking at an eminent boom period. Their motivation was preparation for this boom, whereas Company A's was primarily to firstly survive in their tough economic climate and then to thrive. Interestingly Company A wanted to implement lean, Company B didn't know what lean was, they just wanted to improve. The managing director (owner-operator) of Company A came from professional sales and management roles and eventually acquired the company. The managing director (owner-operator) of Company B had worked his company up and showed less of the trained management skills although he had a good feel for how the business and market were performing.

Preparation Time and Building Personal Lean Knowledge

The initial time in company B was spent in preparation for future change. The researcher conducted this by himself but with feedback from team members. There was involvement in all aspects of the business to understand the business and its value proposition; this included time spent working in the factory, in administration, and contacting customers. Basic processes were mapped and initial gaps in the purchasing and logistics systems were filled. Linking and standardising processes made way for future improvements whilst essentially buying time to build knowledge and confidence for full lean implementation. Although the researcher was experienced in improving systems, applying tools for planning and linking processes, he needed to build his lean knowledge.

As the knowledge of lean built, his concepts shifted from merely the 5 key lean principles to discovering a sustainable approach to lean. The approach was based on the knowledge gained primarily from four texts:

> *The Goal: A Process of Ongoing Improvement, (3rd Revised.).* Goldratt, E. M., & Cox, J. (2004). North River Pr.
>
> *Lean Thinking: Banish Waste and Create Wealth in Your Corporation (2nd Ed).* Womack, J. P., & Jones, D. T. (2003). Free Press.

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[72] Major engagement of product and manufacturing process did not feature so high in initial implementation as covered in this case.

Staying Lean - Thriving, Not Just Surviving. Hines, P., Found, P., Griffiths, G., & Harrison, R. (2008). Lean Enterprise Research Centre.

Switch - How to Change Things When Change Is Hard. Heath, C., & Heath, D. (2010). (1st ed.). Crown Business.

The Goal gave concepts of flow, *Lean Thinking* introduced lean principles in detail, *Staying Lean* opened sustainability and organisational development, and *Switch* further expanded the knowledge of change leadership, giving handles for application.

Planning

A basic action plan was drawn up by modifying those from the literature reviewed. It was further modified as more knowledge was gained. The resultant plan was:

1) Education of senior team members in regular management team meetings (build guiding coalition)
2) Define value in eyes of customer, create the crisis and develop the vision, and set the scenario (presentation to staff as a whole)
3) Establish regular staff meetings for general business purposes and build CI culture
4) Begin with simple 5S implemented and stressed

VSM/Simplified Process Mapping

Process mapping was used in to identify key areas for improvement and help develop the vision. These were quite simplified maps as improvement areas were very obvious. High level detail was not needed. These were in conjunction with strategic planning exercises typically qualitative SWOT and PESTEL.

Giving the Education and Implementing Simple Examples with Senior Team

Senior team members were slowly educated on key areas like flow thinking, visual systems, building healthy habits through standard work, the benefits of staff engagement and employee initiatives. Flow was presented to management with illustration of water systems with bends, leaks, unnecessary junctions, and build-up of waste in lines. Invoicing every day was a simple habit that was implemented in the management team to greatly affect flow through the business. Invoicing everyday pulls every other aspect of the information flow through, exposing problems in other areas. Visual systems were also implemented; office WIP was made visible; rather than hiding them in draws and cupboards, the invoices and quotes could be seen pilling up each day. Additionally a simplistic form of Takt was applied in preparing quotations. It was discovered that the firm on average did 60 quotes in a four week month. The quotes were different sizes however if every workday of the month (20 days) the estimating function prepares three quotations per day then the months quoting is kept up to date. An extension of the system is that the documents for quotation were arranged in priority order and displayed visibly such that the Managing Director could see if the Estimator was on target. The Managing Director then supported as required.

PDCA--Management Standard Work

PDCA was a key factor to accomplishing continuous improvement. The author managed his own office space with standard work and a personalised kanban board that monitored progress on goals. Regular monthly review and reporting to management acted as higher level PDCA. These tools kept improvements on target and ensured their accomplishment. A short but regular weekly management meeting was established for communication amongst the management team regarding general business needs and discussion of improvements. These times were used to impart lean knowledge and provide regularity for the implementation.

Engagement of Staff with Vision and Urgency, Plus a New Identity and Simple Problem Solving

After the senior team had their initial education, the rollout came to the factory floor. A weekly staff meeting was instituted as a regular time with staff to cover basic business needs including health and safety but also as a time to develop culture of improvement. This time gave opportunity to develop staff as well as give them a voice. As the business was small it was possible to do this will all staff. Over a number of weeks the staff vision and identity was developed, i.e. before introducing basic root-cause analysis tools, 5 Whys with a simplified A3.

Each week the meeting took about 15 to 20 minutes. There was a brief general meeting discussion, e.g. workload and staff levels and health and safety before introducing new lean concepts or reinforcing old ones. The meeting also provided employees with a voice that could be heard. To build a new attitude of engagement and initiative taking the staff were asked to think of themselves as Improvement Engineers. Rather than using the Inventor designation (Heath & Heath, 2010) the Improvement Engineer identity was developed. *Engineer* was a title more appropriate and attractive to the employees. The program did not start with an improvement event but by slowly introducing the concepts.

In the first weeks, meeting the goal was to introduce the concept and sow the seeds, beginning to change the way the staff think of themselves without overwhelming. It mentioned the vision to improve because a flood of work was coming, and the business needed to work smarter not harder. The new identity for improvement engineer was introduced as an additional title for employees; that is a welder is not just a welder but a Welder & Improvement Engineer and a driver is a Driver & Improvement Engineer. An example of a simple improvement was given (a tick box on job card). There was a good response to the new concepts presented also some old frustrations for things not changing in the past, highlighting the need for initial wins and momentum. Staff approached management afterwards with ideas for changing factory and dealing with old stock.

The second week a visual presentation was used to develop emotion regarding the need and a small training in problem solving was given. Employees were reminded of the *''Improvement Engineering of Improvement Engineers''* as the theme to promote the new identity. The vision was supported with an emotion grabbing visual (and taste) of current workload versus the coming workload (Figure 15). A time line was presented across the cafe table: day 1, day 2, day 3, day 4 and day x. Cake was used to represent the workload increasing da by da. Day 1 to 4 workloads were represented by cupcakes. The day X workload, the eminent boom of work, was represented by a large chocolate cake. The meeting emphasised “We need to be prepared to eat, well trained like the Japanese eating champion who competed against the bear. Otherwise, we will still try to eat but get sick quickly. We will not eat as much as the big bears but we can eat our fair share”. This example was continued to give a destination postcard of what the shop could look like and how jobs could flow to avoid “indigestion” and that "we can have as much as we can eat!" Discussions alluded to profit sharing. Given the company does well it is only logical to share with employees. This was a truly engaging session, especially as the employees got to interact with the visual example by eating it. Later a cake made of black beans was presented to invoke thinking outside the square. The less tasty cake had much less impact on staff.

Figure 15 Cake Motivation: example of presenting the vision and need for change in an emotion grabbing way. On the cafeteria table is a timeline illustrating workload increasing by the amount of cake. "We can have as much as we can eat!" (Image: A. Pearce)

The seeds of problem solving and PDCA with A3 management techniques were sown. This was based on a simple problem solving with 5 Whys. It was stressed how an idea should be something from the floor i.e. what the staff want it. Also gave example of more complicated root cause analysis to find out real systematic problem. There was a consciousness not to do too much or overload the workers so further problem solving exercises were held back.

Improvement Engineer Program

At the fourth meeting, a further development of the staff identity was the registration to be an Improvement Engineer. For this, a formal registration form was drafted describing the role of an improvement engineer (see appendix, p. 375) and all staff members were requested (but not forced) to sign up to the program. This sign up strongly reinforced the new identity and seriousness of management. This from was also used when hiring new staff to bring them into the developing culture. The additional role was presented as a good addition for their curriculum vitae. With the improvement registration, an OFI (opportunity for improvement) form was produced. This provided a system that enforced staff ideas to be noticed. One response to the Improvement Engineer Form was "do I, a painter need to sign" the return response was, "yes, you are the best to say how to improve painting."

All staff signed up except for one older craftsman.

Gemba MBWA

The implementation was supported by observation and MBWA (management by walking around). It was important to see the real state of the factory and gain regular feedback whilst building relationships with the employees.

Process Continued

This process continued with reinforcing ideas and developing employee identity for problem solving. Some small teams were made for initial 5S activities and weekly PDCA was applied. The workshop foreman began to show more initiative in leading change and employees were encouraged to focus on what was frustrating them.

A certain level of persistence was required with the activities. For a small example, presenting 5 Whys got some grumbles at the third "why" but when, at the fifth Why, the systematic problem was uncovered it gained respect. Much more persistence was required in other areas; for example, a kanban style planning systems got resistance but eventual ownership was handed over and the systems appreciated.

Staff Resistance

Most staff appeared to engage well. One older craftsman seemed disengaged but possibly just disheartened with company direction and the outlook for his future, he was feeling left behind. Attempts were made to remedy this but it seemed an inflated ego, not helped by previously unkept promises, made the transition difficult.

There was an occasion of short lived resistance with the previously mentioned planning board. The style of planning was new to the manager who challenged it. They were used to simple whiteboard lists as opposed to the card system proposed. They could not visualise how the system would work and realise its benefits until it had been running. In this case, resistance was short lived once the system was in operation. It seems there is room for believing through seeing in some instances however there is risk that staff would disengage and not re-engage or be willing to cooperate whether or not the “improvement” was beneficial. The workshop foreman however was immediately happy to try the planning board, it was something new for him, but not encroaching on something he was already doing.

The main resistance to change was departmentalised. Even in a small business, the accounts department (one and a half persons) found it difficult to accept the interrelatedness of the whole. They desired to optimise their systems not recognising the effect on the whole flow of information. It is expected this was partially due to a feeling of seniority based on age and perceived experience as opposed to the younger change agent.

Further Insights

First, There was concern for on-going education. A very basic education had been given to the team. The management team had been given a copy of *The Goal* (Goldratt & Cox, 2004). The foreman read *The Goal* (after having been given it two months) earlier and became excited about the concepts. A business advisor also read *The Goal* and became full of enthusiasm. However, other leads were more reluctant to read. The enthusiasm of the foreman did start to insight others though.

Second, for the change agent, two points were needed 1) confidence and 2) confidence. Once the knowledge was there and the necessary ground work was done (defining value and looking at the future state) there needed to be a level of confidence in the change agent, not arrogance and recklessness but the necessary confidence to execute change. It was a big trap (for the researcher) to over analyse and lose confidence. This was difficult without the support of an external mentor confirming the action plan. *It is possible that discouragement would be a cause of failure, that is not taking a "leap of faith" to lean* and being comfortable with minor process change, stuck with status quo, the way it has always been done. Company A in essence stuck with status quo.

Third, it was a concern that the true value of engaging staff on the floor was not recognised. Planning for factory rearrangement was accomplished from the top down without any bottom up input. *It was difficult for the management team to recognise the expertise that was on the floor* and the benefit of discussing improvements to factory layout with the staff doing the job. There was an instance where the managing director arranged shelves for the factory without discussing what was best with the foreman. One factor in this was that the managing director (an owner operator) was once on the floor and felt he knew the job best, He may have in the past but really that was some years ago. And even if his knowledge was up to date, the other employees needed to be engaged.

Finally, as the systems were integrated and defined administration staff began to get frustrated. Problems came to the surface; this of course is expected and welcomed because they can then be solved. Frustration was also at people not behaving exactly to the new systems. There was an inclination to (A) get frustrated and (B) put in additional control and systems without analysing root cause. They would implement change quickly in "band aid" fashion not thinking (1) where problems really came from or (2) having a growth mindset towards other staff; recognising things take time and change is a process particularly in learning new behaviours. This required education for one office manager and in turn for her to educate others as needed.

Actually their needed to be a celebration of what was working, what was going well, staff were following systems much more than any time previously but this was a stage of change.

Case B Implementation Outcome

The researcher was involved in many of the daily struggles of implementing lean change. This necessitated application of novel thinking to apply lean and organisational development according to the many situational variables—product type, and management and staff attitudes. This significantly grounded the research in reality.

- This was a solid industry study for the researcher, grounding the research in the reality of lean implementation.

In contrast to case A there was time given for the development of lean knowledge.

- Lean knowledge provided the change agent with the vision to implement lean in a holistic sense.

The researcher's involvement was limited to 11 months. The early part of this was spent in preparation including basic system implementation and training of management. Factory staff was not involved until 6 months had passed. The remaining months were really insufficient to develop true lean. Some have stated 3 years as necessary for a sustainable lean culture (M. Wilson et al., 2008; J. P. Womack & Jones, 2003). Once the researcher left the organisation, the office manager was seen as an on-going change agent to implement change further. A *Company B Production System* document was developed around basic flow methods and concepts to engage staff. Concerns over who would carry that out were voiced. In the weeks before departure more opportunity came to train other management staff (whether they realised or not). In the last weeks the fact that the change agent was withdrawing had meant some of the other staff took up the needs (e.g. calling a schedule review) showing ownership of what at earlier times had been thought of as not necessary. Positively:

- The company was left with basic tools for continuous improvement.
- The influence of the Improvement Engineer program promoted the feeling of staff initiative being welcomed and important.
- The company has come into the expected boom period for its industry and developed further systems and procedures with growth of the business.

But, it is reasonable to believe that:

- The implementation would have achieved more with longer presence of the change agent who was driving for improvement and had developed a significant level of lean knowledge.

The insights were developed and incorporated in the research hypotheses. These are discussed at the end of this chapter.

4.2.3 Case C—Company A

Case C was a revisit to Company A. The researcher volunteered to assist with implementation of lean technology systems and act as lean analyst. This was a 7 month embedment with on-going communication on progress. The focus was on technology implementation, positive changes were made, but there were significant challenges with staff. Much of the analyst aspect is included as the write up to Case A but this case included specific insights.

The advisory board of Company A conducts regular strategy sessions. These identified that lean business systems and particularly the technology tool ERP was a strategic priority. To compete within the now international market Company A wanted to show the value of a local supplier by reducing lead time and manufacture costs, and developing ability to handle demand variability (e.g. achieving flow and eliminating wasted effort including reducing run setups) as well as increasing goods quality. Lean methods can be used to treat these areas; it was therefore a strategic priority.

ERP is not strictly a lean tool but can be included in a lean system. ERP was prioritised as it can be used to significantly decrease administrative requirements and thereby relieve bottle-necks in administration. For a small business like Company A, it is unique to require full ERP capability. But Company A had significantly high administrative requirements due to their particular product mix and customer requirements.

Tool Implementation, ERP Technology

The implementation of ERP at Company A went through a long planning process. It had been a strategic priority for three years and had been selected and in planning for two years. The author was involved in this process and offered to assist as a case study once implementation begun. This review does not directly access the technology itself and specific situational variables i.e. Company A product mix. This review targets key aspect of organisational development.

Throughout the process, various levels of support were provided to staff. There was a regular weekly meeting that lasted one to two hours and discussed the progress of the system. At this time, the vision was presented and questions addressed. Systems were developed for recording common questions and customised standard works procedures were produced. Day to day support was readily available from the manufacturing manager and telephone support from the ERP provider. Consultants from the ERP provider also assisted with site visits. The author provided support services a couple of days per week.

It was evident from the outset that relatively small actions had a big effect on success. One small comment at the start of the implementation led to management sensitivity and insecurity of the accounting accuracy. This lead to a delayed rollout, holding back on conversion from existing systems and issued in a decision to run two systems in parallel for a year.

Many employees were frustrated from the outset with any problems that rose and voiced negativity that was contagious. They didn't have the journey view for the change; instead of thinking this will take some time but ultimately would have positive results, they just saw negatives. Also, they didn’t have a growth mindset for themselves and their own ability to manage the change.

Resistance to the change was identified as A) employees didn’t understand and B) employees didn’t trust the system. Group affects were also relevant. These effects were seen among staff groups but especially strong with members of the same family. The negativity affected attitudes of other employees before they had opportunity to use the system. Typically, this was overcome when benefits were proved, but the transition was made more difficult.

In some cases staff struggled unnecessarily without asking questions. For a long time an intelligible member of staff was bogged down manually rounding time entries, an easy fix once the question was asked. Another user struggled for months with icon size due to poor eyesight but all that was needed was a quick screen resolution change. A mutual Q&A format was provided and staff communicated but they did not voice certain struggles that were easily resolved. They didn’t think to ask “is there a better way?” in some situations or to ask until satisfied with the answer. This was possibly due to lack of technical aptitude and realising the simplicity of minor software adjustment. Technical ability and aptitude to pick up new technology was relevant. Some employees were happy to work with the system and make the system work for them. Others were so afraid of making a mistake that they were paralysed unwilling to take appropriate short cuts.

In this implementation, improvements were typically driven by employee’s frustrations and cries for help, deviating from the set progress plan. Sometimes certain illogical or unnecessary technical changes were made in order to appease staff and show support. This was important in keeping employees engaged in the process.

Overall, the time frame for implementation change did take longer than expected.

Case C Implementation Outcomes

Overtime staff became more familiar with the new ERP system and the pains of implementation showed positive results.

Case C Research Outcomes

This case added perspective to a significant tool implementation that effected an entire organisation (be it an SME). Notable is:

- Technology was well selected but resistance from staff was strong.

Resistance seemed especially from lack of knowledge and strengthened by group effects.

- Staff didn’t understand the tool and couldn’t visualise the benefits of it.
- Negativity bred negativity, and a growth mindset was needed.

The challenge of organisational change highlighted importance of appropriate method selection:

- Some changes were implemented not because of their benefit but because it was a step, keeping staff engaging staff.

Methods need to be selected not only with view of their benefit but also with view of organisational development (OD) for sustainability. Without considering OD, there is increased risk of failure. As a development of case C, risk management methods were explored for lean implementation decision making.

4.2.4 Case C—Development—Risk and Decision Making

The importance of decision making during Case C highlighted that each one involves risk. For example, lean includes many methods and supporting processes. Figure 16 illustrates some of these.[73]The selection and prioritisation of these methods is needed for the success and sustainability of lean. Besides the risk of an implementation as a whole, there are risks for its various facets and stages. It is believed that each aspect should pass through a risk assessment and analysis of some kind to determine the treatments necessary.

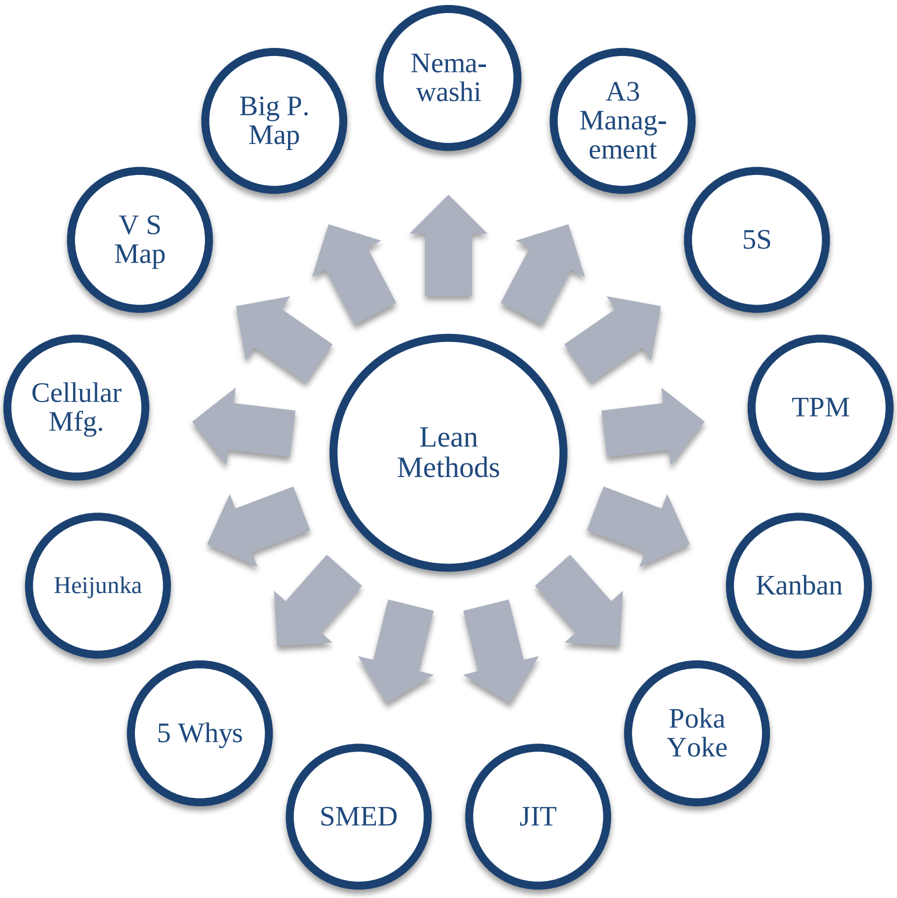


Figure 16 Lean methods: a selection of some (not all) of the lean methods and tools. The large number of tools indicates the importance of having a selection criteria and prioritisation method for implementation. (Image: A. Pearce)

[73] See Figure 196 (p. 696) for an description and analysis of tool use.

Merging Risk and Lean Management

The approach to this problem was to reconceptualise the decisions surrounding lean implementation as a risk management problem. Risk management had been shown to be complimentary to lean (see literature review p. 69). Consequently, a conceptual framework was developed for treating lean in this way. From this, a method was created for assessing the risks of lean practices in a specific organisational context. Then the method was applied to a case study firm.

First, as there is little evidence of the merger in literature (p. 69), the research answers "to what degree does lean thinking and risk management thinking align?" The method was to recast the principles of lean into those of the risk management standard. This was accomplished strategically and to the ISO standard principles and framework.

Secondly, risk management methods are applied to the implementation of lean in a specific case study. A technique for prioritising lean methods was developed for improving implementation success. This demonstrates how risk management and lean can be integrated in the decision making processes of lean implementation.

The outcomes of this work were published in the Journal of Industrial Engineering (Pearce & Pons, 2013). The developed paper can be found in the appendix (p. 342).

Showing Risk Management's Compatibility with Lean

The Strategic Level

Lean as a strategic business transformation fits with strategic risk management. Lean can be considered as a treatment for strategic risk. Threats can be minimised and opportunities maximised by the application of lean.

Lean systems work to reduce effort, space, required capital, and lead time whilst increasing quality and decreasing the cost of quality. Whether a strategic plan is to maximise the opportunity of more sales or minimise the threat of lost market share, lean treats both of these risks and presents a new value proposition to customers.

A common threat in today's market place is the loss of profit to fierce overseas competition. Lean enterprises find they can compete with cheaper overseas labour markets by continually reducing waste (Chapman-Smith, 2012; J. P. Womack & Jones, 2003). The dynamically changing market place presents another risk. Businesses need a dynamic culture of empowered emergent change to respond to the fluctuations in the external environment (Burnes, 2005). A culture of dynamic change and enabled learning goes along with lean and is a treatment for this threat (Burnes, 2005; Hines et al., 2008; Liker, 2004).

Lean also has its own methods for analysis of risk. Techniques like value stream mapping provide a means for identifying opportunities to improve flow and reduce wasted effort. A value stream mapping exercise firstly analyses the current state of a product/service flow. It then maps out the *treatment* in the form of a future state chart. In effect, this process involves discussion and decision making regarding the appropriate treatments to maximise opportunities. Various other tools also support decision making and treat risks at different levels. For example, *5 whys* (asking why five times) is a simple root-cause analysis tool for investigating an issue to the extent that the risk of repeating an issue is minimized and preferable eliminated. *Total productive maintenance* is another treatment used to minimise down time on machinery and identify areas that have a risk of failure. These latter examples may seem more trivial, however it is clear that lean methods can be used in identifying opportunities, supporting decisions, and treating risk.

Via the ISO Standard

The risk management BOK is embodied in ISO/DIS 31000 (2009) can be compared with the contemporary understanding of lean. The recasting shows the clear complementary and mutually supporting nature of lean and risk management as described by the standard. This is particularly with the 2009 standard's "*greater emphasis and guidance"* on risk management implementation and continuous improvement (ISO/DIS 31000, 2009). As lean is also the outcome of continuous improvement thinking, there is an automatic synergy with the risk management standard.

Risk Management Principles

1. Creates and protects value
2. Is an integral part of all organisational processes
3. Is part of decision making
4. Explicitly addresses uncertainty
5. Is systematic, structured and timely
6. Is based on the best available information
7. Is tailored
8. Takes human and cultural factors into account
9. Is transparent and inclusive
10. Is dynamic, iterative and responsive to change, and
11. Facilitates continual improvement of organization

Lean Summary of Principles

1. Focuses on creating customer value
2. Integral part of organisations processes and procedures
3. Lean thinking and techniques support decision making
4. Addresses waste through optimisation of flow
5. Has structured yet dynamic processes and methods
6. Improvements based on review of current conditions and value in eyes of customer
7. Implementation tailored to the organisation based on key Lean principles
8. Involves respect for humans and an enabling culture
9. Inclusive of entire system (not compartmentalised or focused on local efficiencies)
10. Enables dynamic learning organisations of emergent change
11. Facilitates continuous improvement for perfection

Figure 17 Principles of risk management (ISO/DIS 31000, 2009) alongside the recast principles of lean thinking. This shows the mutually supportive and complementary nature of risk management and lean management.

It is sensible to start with the principles of risk management (RM) and lean. RM has a clear set of principles (ISO/DIS 31000, 2009), whereas the principles in lean are more tacit. Therefore, the contemporary understanding of lean was recast into a set of principles, and was compared and contrasted these with those from RM.

The results are shown in Figure 17. The major difference is the function of risk management is to explicitly address uncertainty, whereas lean explicitly addresses wasted effort through the optimisation of flow. Nonetheless, there is a clear fit between the principles. Both lean and risk management focus on "value". The risk approach protects value and lean supports this by focusing on providing customer value. Both are systematic and data-driven. Both implementations are tailored to the organisation, take into account human and cultural factors, and aim to be inclusive of the entire system (not compartmentalised or locally focused) and include all stakeholders in the processes. Both are dynamic and responsive to change and facilitate continual improvement of the organisation.

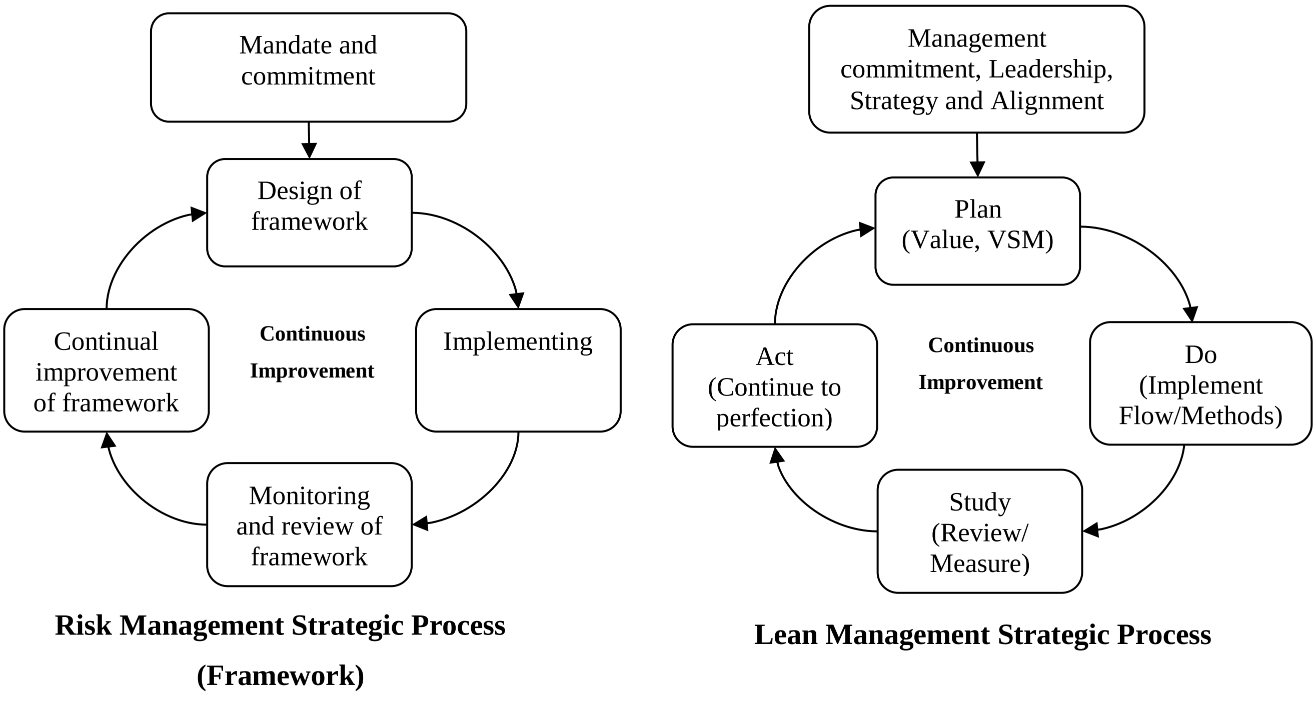


Figure 18 Risk management framework (ISO/DIS 31000, 2009) compared with lean management.

Next, the frameworks are compared. Again, RM is arguably more organised in this regard and already has a framework; a comparative one for lean is created. To do this the Lean Iceberg Model (Hines et al., 2008) and the five principles of lean (J. P. Womack & Jones, 2003) are merged. The results are shown in Figure 18.

The lean concepts are synonymous to those of the risk management strategic process. The mandate and commitment of the framework is synonymous with management commitment, strategy, leadership, and alignment within the organisation. This is made more clear from the detailed definition in the standard (ISO/DIS 31000, 2009; cf. Hines et al., 2008). The cycle itself—design, implement, monitor and review, and continually improve—is a simple PDSA (or PDCA). This cycle came out of the quality and continuous improvement field (Deming, 1986; Moen & Norman, 2011) and can be seen in lean's five key principles (J. P. Womack & Jones, 1996)—defining value and planning for flow of value, doing the implementation, reviewing and continuing to perfection.

The final part of the conceptual model is an integrated process model. This was achieved by overlaying the lean processes on the risk management process, see Figure 19. The on-going communication process, indicated as key to good risk management, is very much a part of continuous improvement and lean. Toyota developed a particularly efficient and effective means of communication to allow for consensus and collaboration as well as engagement and input from all staff. Techniques such as A3 management, with the catchball process or nemawashi are integral to the TPS and lean learning organisations (see Hines et al., 2008; Liker, 2004). Establishing the context is synonymous to defining value from the customer viewpoint. The context in risk management strictly is both internal and external looking and so in reality crosses with the mapping of the value stream. VSM was included in the risk assessment section of the model. As an assessment process, VSM looks at the current state and opportunities for improvements to get to a desired future state. In the assessment analysis, the tool 5 Whys was identified for root cause analysis (RCA). Other tools could be used for the same purpose (e.g. Ishikawa fish bone diagram). A3 management is shown for risk evaluation. A3 management is used for reporting, formulating, and passing on ideas in a communication process. Risk treatment is achieved with the appropriate application of various lean methods. These are chosen through the assessment process. Additionally, the PDSA cycle is built into the process for monitoring and review.

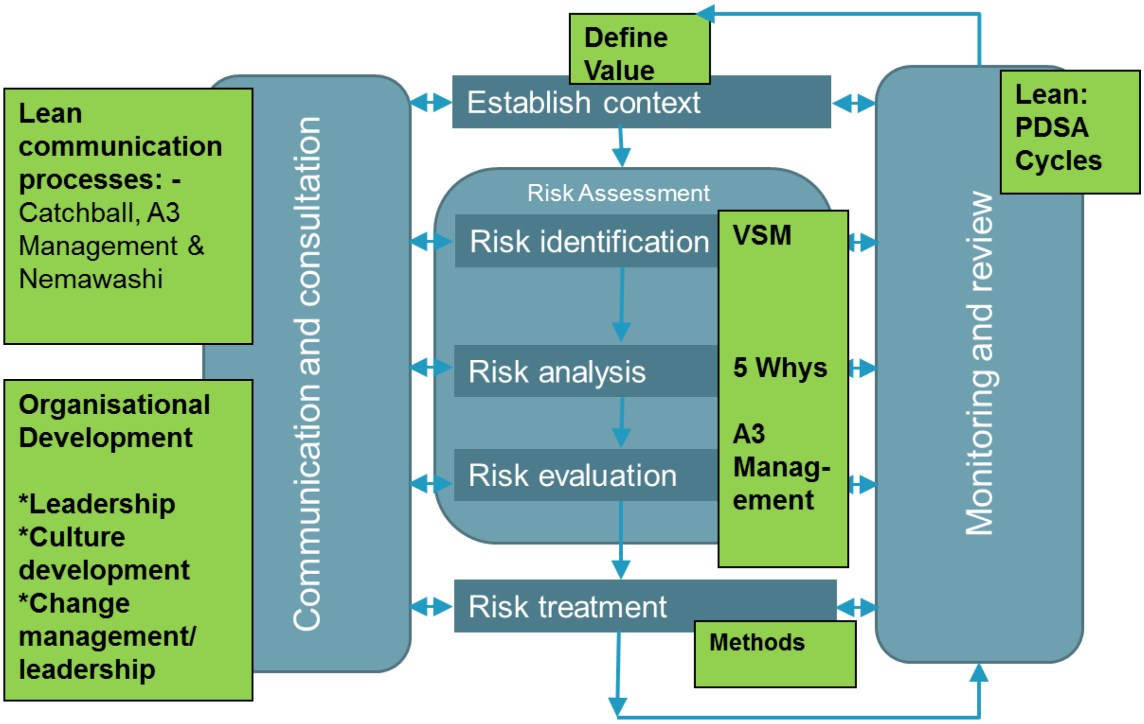


Figure 19 Lean processes overlaid on the risk management process per the AS/NZS standard (ISO/DIS 31000, 2009).

It is not surprising that the risk management approach matches with lean management. The RM standard strongly represents the quality and continuous improvement systems, which also were parents to lean manufacturing (Holweg, 2007; J. P. Womack et al., 1990).

Developing a Mechanism for Implementation

Having achieved a broad conceptual integration of risk and lean, the next step is to develop an operational method, a mechanism for the application of RM to lean decision making. This work assumed that someone contemplating implementing lean has already acquired background knowledge of various lean tools and principles (see Figure 196, p. 369). The focus was to develop a method for supporting the decision-making of practitioners by identifying the factors that should be considered. This was done by following the risk management process, taking particular care to represent the organisational factors, as these are known to be crucial for successful implementation. The results are shown in Figure 20.

Risk Management Process AS/NZS ISO 31000		Lean Implementation Application
Set Context		Lean systems reduce waste activities and increase value to customers, thereby increasing productivity and profitability. The internal context is the resources, staff culture, and the need for sustaining the change. The external context is the market conditions.
Perform Risk Assessment by: (see 1-3)		
1	*Identification of sources, areas, impacts, and events.*	Lean methods have risks associated with their use, benefits, and detriments impacting various areas.
2a	*Analysis to understand the risk its causes, sources, (see 2b) and other pertinent factors,*	Qualitative discussion of the detriments and risks to sustainability of lean methods (source) and entire lean implementation, in context of the tools and the consequences of tool use.
2b	*Consequences and likelihoods, confidence sensitivity and other pertinent factors,*	Expert-opinion (qualitative) is incorporated as charts. The chart shows the qualitative assessment of likelihood and consequence for various tools.
3	*Evaluation for assisting the decision making process including risk tolerance of parties*	In the context of organisational change, methods are sought that will support sustainability not just process improvement. There is a decision from management (a mandate) to support lean in order to meet business goals but wisdom is required in the lean implementation for building a culture for sustainability. This involves selecting the right methods at the right time. It is necessary to get “wins” in the view of the staff up front. This is not necessarily the biggest wins but small wins to gain momentum and staff confidence. At the start of an implementation high risk cannot be tolerated even when high return is possible i.e. where staff are not yet engaged to support a difficult method (like JIT). Failure could ruin future chances of success and engagement. Communication at the start of an implementation is necessary to impart the vision and break down goals to give critical steps for change.
Prescribe Treatment of Risk *To maximise benefits and minimise detriments – increase the positive and decrease the negative likelihood and consequences.*		Treatments prescribed in general cover the following: Adequate communication with development of new identity for staff; prioritisation of time for business running and improvement activity; and prior conditions met adequately (including previous methods, training of and engagement of staff) for any methods implemented.

Figure 20 The process for risk management according to ISO 31000:2009 applied to lean implementation.

Process

Standard tools for the strategic scanning of risks are PESTEL and SWOT. These are for environmental scanning and identification of risks in the form of internal strengths and weaknesses and external opportunities and threats (hence SWOT); these may be characterised by political, economic, and other variables (hence PESTEL). The integration of these with strategic risk management has already been demonstrated (Pons, 2010a). The strategic risks are primarily qualitative, as opposed to quantitative, and hence a matrix mapping is appropriate (as opposed to quantitative treatment).

It is possible to apply qualitative graphical techniques to represent the risk for lean implementation. The impact of each specific lean tool and the likelihood of achieving that impact can be plotted as orthogonal variables, see Figure 21. In this regards there is the exchange of *impact* where the RM method uses *consequence*, but the two are comparable. The impact is the effect on the organisation in regards to lean transformation.

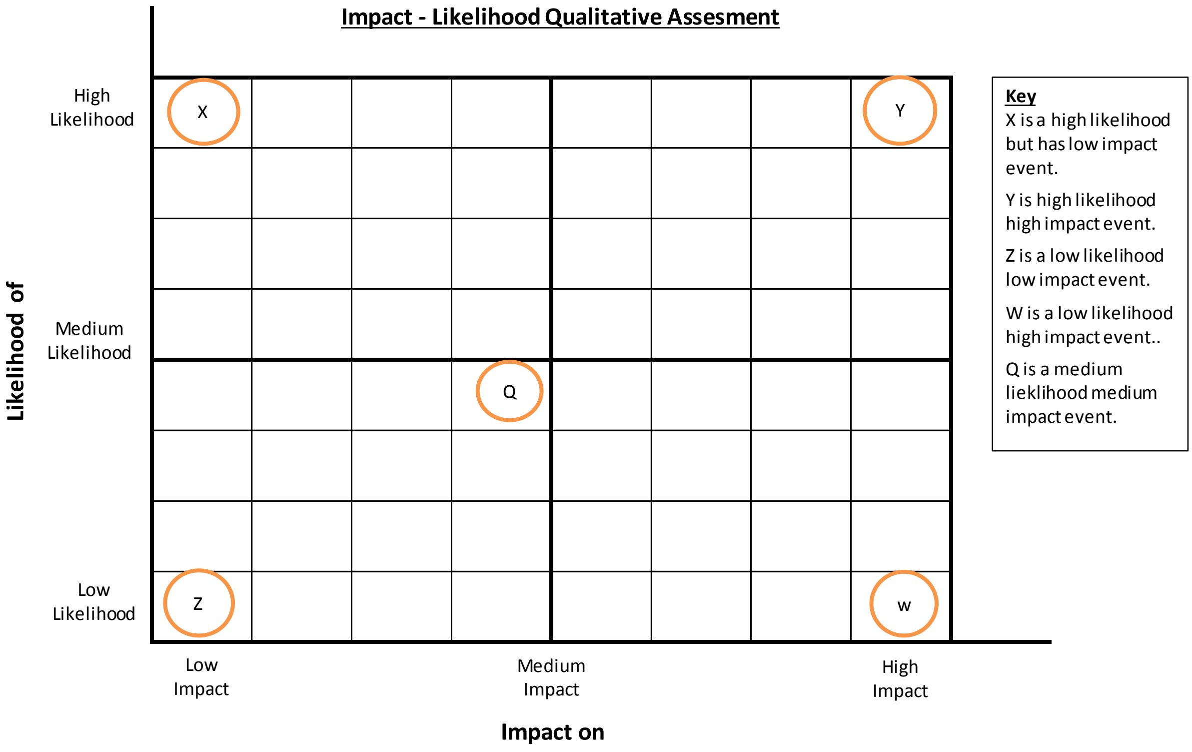


Figure 21 Likelihood - impact qualitative assessment matrix by A. Pearce.

The chart aids in identifying where initial wins or easy implementations can be targeted. Note that high likelihood (low difficulty) events can be critical even if the immediate impact is not high. This is because gaining small wins is particularly important at the outset of an implementation to ensure momentum and sustainability (Heath & Heath, 2010; Hines et al., 2008; Karl E. Weick, 1984).

In summary, a method was established showing that the implementation of lean can be considered a type of risk, with potential positive and negative outcomes. This method is able to identify the risk associated with a specific aspect or tool of lean. The next section illustrates the application to a case study.

Application to Case Study

Characteristics of the Firm

The case study is a small to medium enterprise (SME) that is a make-to-order and design-build manufacturer specialising in complex parts and assemblies. It is representative of the many SMEs that are actively trying to decide which parts of lean are relevant to them, and how to implement them. The firm ('Company A') is based in New Zealand and has 20 employees. Typically, production is of small to medium size runs, low-volume high-mix. The firm possesses an advanced CNC equipped plant, has precision assembly capability, and takes pride in project management i.e. providing the full solution including concept and design development, build, commissioning, delivery, and after-sales support.

Historically lean has been the preserve of the large high-volume manufacturers typified by the automotive industry. However as the lean method has matured and spread to other industries, so it has been applied to smaller and more specialised firms, like the one considered here. Lean adoption is also driven by competitive pressure, particularly the opening of global markets, and the resulting exposure to more competitors. Therefore, even the small firms have to consider how they preserve competitive advantage and deliver value to customers. These firms, being small, typically cannot afford to employ specialised staff for this purpose. They also have limited resources for implementing new programmes like this.

Strategic Mandate

In the case of this firm, the need to adopt lean was a strategic decision identified at board level. To compete within the international market, the firm needed to show the value of a local supplier by reducing lead time and manufacture costs, and developing ability to handle demand variability (e.g. achieving flow and eliminating wasted effort including reducing run setups) whilst increasing quality. Lean methods can be used to treat these areas and therefore lean was considered a strategic priority.

At the strategic level, the firm needed to treat key factors for success and sustainability of lean. These factors were identified (e.g. Heath & Heath, 2010; Hines et al., 2008; Liker, 2004; J. P. Womack & Jones, 2003 and elsewhere in this work). Factors are summarised below:

Change Leadership:	Leadership commitment with the vision and its communication for engagement of staff. The initial steps of change and on-going "wins" for momentum of change. The development of a new organisation identity.
Managing Internal Resources:	Physical, human (availability and capability), and financial resources need to be managed for training, learning and implementing changes.
Managing External Resources:	Use of a consultant (sensei) or other external resource for training.
Other Factors:	Market conditions and forecasts (risk), demand variability, and expected product mix among other things.

Evaluating Risk within the Lean Strategic Principles

The author was embedded 0.5 FTE[74] for six months in the firm as part of a government-industry-university partnership. This provided the contextual knowledge for analysis. Each of the strategic principles and tools were taken and evaluated for this firm's context, the impact and ease of implementation (see appendix Figure 196, p. 369). These were then plotted on the risk chart, see Figure 22.

[74] Full Time Equivalent

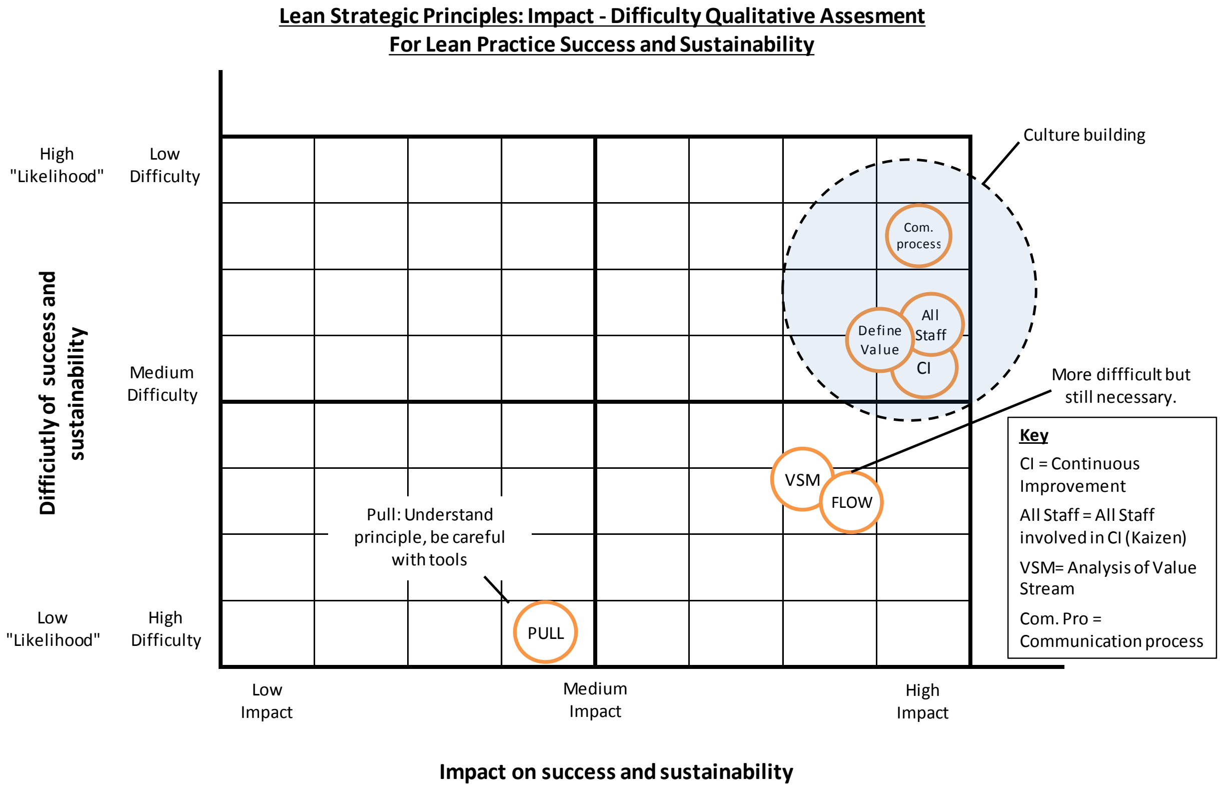


Figure 22 Strategic principles: lean's key principles and higher order processes qualitatively assessment of their impact and difficulty (likelihood) of success and sustainability (reference case Company A). (Image: A. Pearce)

All the principles in this first set are of a higher level and are seen as critical to lean success and sustainability. However, it is important to understand the challenges or level of difficulty faced. In the representative case, particular areas of difficulty were observed around process flow, e.g. flow and value stream analysis and application of pull systems. This is because of the make-to-order nature and complicated processes of their business. This is reflected in the *Likelihood–Impact* chart for these factors.

Figure 22 shows the medium level difficulty but high impact of *defining value*, and having all the staff involved in enterprise-wide *continuous improvement*. Defining value is essential to understanding what the customer desires and therefore, identifying what waste is; i.e. what should be eliminated through improvement. The communication process presents the vision to all the staff, supports staff engagement, and the development of a learning organisation; hence, it is also high impact. *This suggests that the big wins for a make-to-order enterprise like this would be in the culture excellence for continuous improvement and not so heavily in the process flow tools (although process improvement would occur as a result).*

Analysis of the value stream and development of flow are assigned a medium-high impact. They are still critical to the process of improvement but not as high an impact in Company A's case.

Pull is very difficult in Company A's case and would need particular adaption as suggested in the table. Company A may need to use pull of order to pull paperwork but push material to the process for flow. This would change where higher quantity production is permitted and even temporary or isolated flow lines could be introduced.

Prioritising Lean Methods: Company A Case Study

There are many different methods or tools of lean. These were each evaluated for the Company A case, in a way complementary to the strategic principles. The likelihood and impact of these methods is plotted in Figure 23.

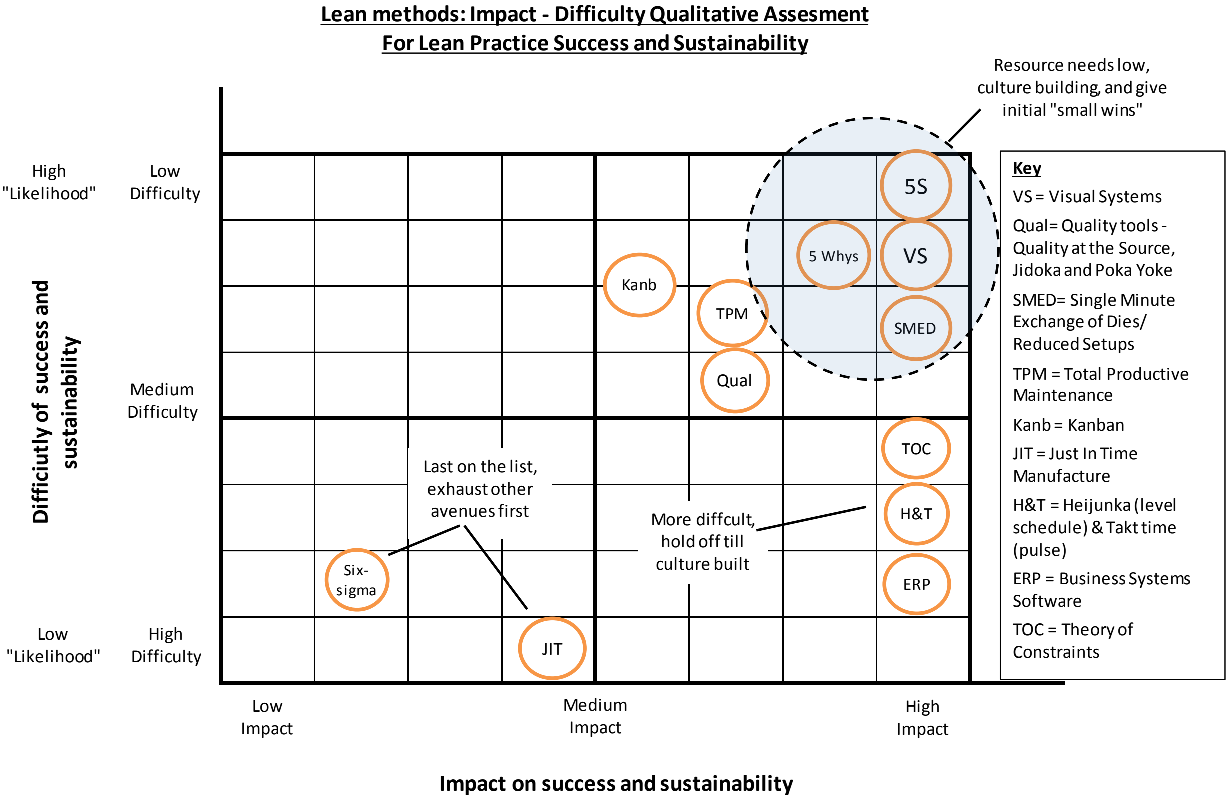


Figure 23 Methods: selection of lean and complementary methods with a qualitative assessment of impact and difficulty (likelihood) of success and sustainability (reference case Company A). (Image: A. Pearce)

The justification for the judgments of impact and difficulty (Figure 23) is brief. This requires a contextual knowledge by the person performing the assessment. In this particular case, the researcher was seconded to the firm as part of the research project, and spent considerable time learning the context in which Company A operated. The assessment tables are included in the appendix (Figure 196, p. 369) and provide insight to the process.

The purpose here is to identify small wins (sometimes called 'low hanging fruit') to increase chances of sustainability. Here the tools more applicable to the make-to-order business are featured in the *top right corner*. In contrast, the tools for fine improvement of production efficiency, e.g. six sigma and JIT, are in the bottom left. These were assessed as particularly difficult to implement in this particular situation, and the benefits would be limited. Implementation of TOC thinking would be more beneficial than six sigma or JIT in this case. Kanban is positioned in the middle, and while (in this situation) may not be relevant for pulling production, it could still be useful for ordering consumables. Managers and business owners at Company A broadly endorsed the validity of this analysis of the situation.

Implications for Company A

Of interest is the high impact of ERP in Company A's case. This is something difficult to implement but if implemented right could have great effect. This is particularly because at Company A production was partially being constrained by flow in the office. ERP implemented correctly would simplify quoting, planning, purchasing, and general data entry requirements which are identified as serious bottlenecks at Company A (more so than specific physical production processes). It could also give other benefits such as business reporting. Company A has much to benefit in understanding the holistic nature of its systems and the interaction between the factory and office processes.

Resource constraints are significant in SMEs, and determine how much the organisation can achieve at any one time. In this particular case Company A had just embarked on an ERP implementation that was somewhat separate from an enterprise wide lean journey. Because of the difficulty of ERP implementation, the suggestion would have been to hold off all other lean initiatives (except for some higher order principles) until ERP is well achieved and the resources are freed to focus on other lean implementation activities. This also implies; if they had a clean slate, and had not begun implementing ERP, it may have been beneficial to implement simpler tools first. This could have benefited them with further staff engagement and building of culture-excellence before implementing ERP with its higher requirements on resources and perceived level of change.

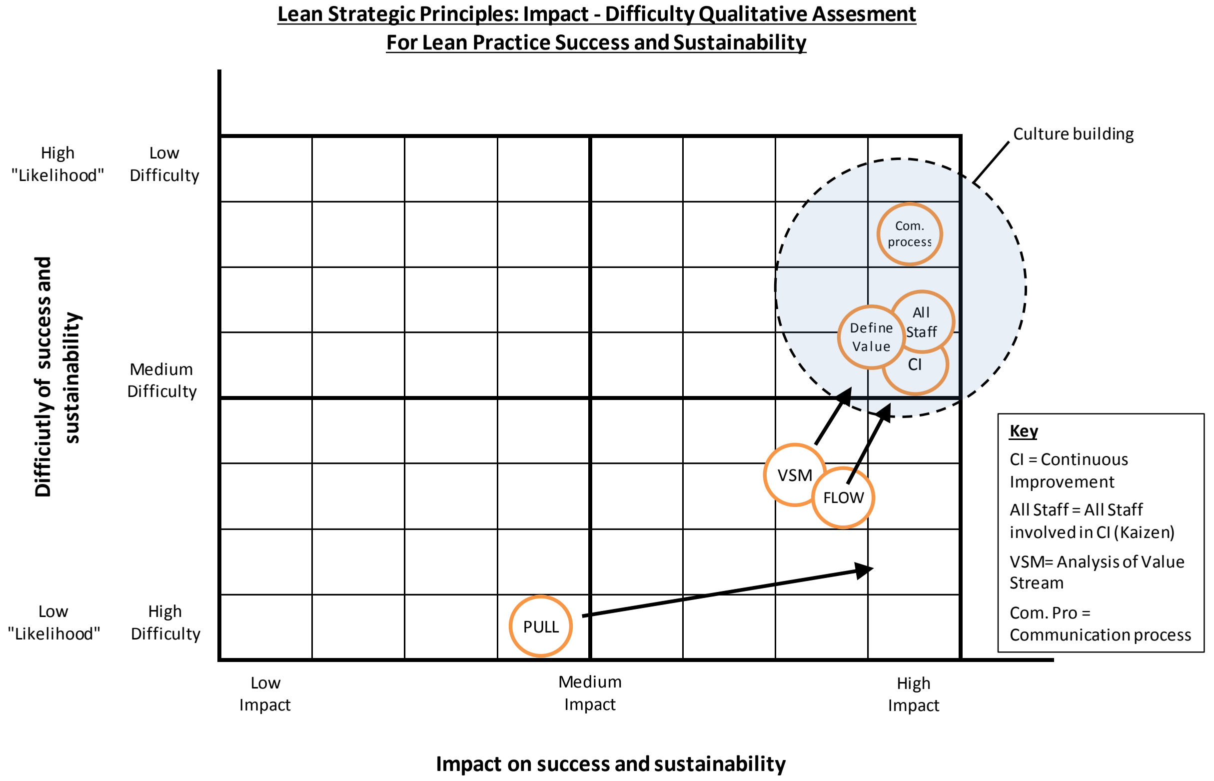
<u>Beyond Production</u>

Lean has been applied effectively beyond manufacturing or production businesses. Although Company A is a manufacturing business was observed that they had many gains to be made in their administration centre (hence a high priority for ERP). Whether or not the physical transformation of goods took place in their own workshop there was much waste to be eliminated in their office. These lean office gains illustrate the competitive advantage of lean beyond manufacturing businesses.

Application to other manufacturers

The implications would be similar for other make-to-order, design-to-order, job shop SMEs, although ERP requirements may drop where products do not demand a lot of records, and data entry or process control.

For firms of higher production (high volume, low product mix) more relevance is seen in the emphasis on process flow principles and tools. This and other likely changes have been illustrated by placing arrows overtop of the previous charts, see Figure 24.



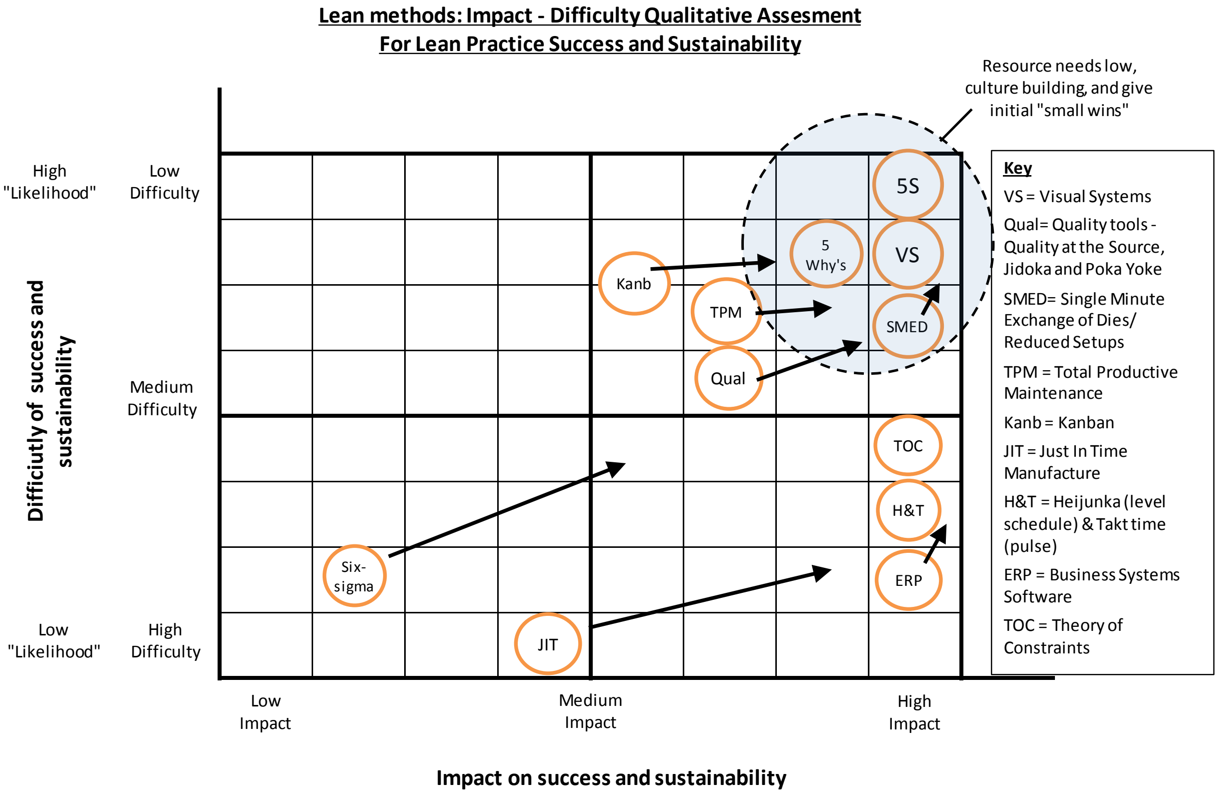


Figure 24 Methods and strategic Principles for an alternative scenario. Indicative qualitative assessment of impact and difficulty (likelihood) of success and sustainability for higher production volumes as depicted by arrows. (Image: A. Pearce)

4.2.5 Case Study Outcomes

The investigation into lean practice in New Zealand contextualised the key issues for success in the New Zealand setting whilst the implementation cases were more specific through embedment. Being embedded in industry and leading implementation change really grounded the research in reality. Thus the key outcome is summarised:

- A practical grounding of the research was achieved with the first hand application of change leadership (struggling with challenges of implementation) in a real world setting.

This study highlighted key issues in handling staff and their resistance to change. Financial situations as well as management attitude were discussed. Particularly the challenges faced necessitated skill in application of organisational leadership, lean techniques, engagement, and education. Primarily lean knowledge was highlighted:

- Developing the knowledge of lean and skills for implementing change was shown to be beneficial to success (case A as compared with case B).
- Erroneous knowledge of lean was highlighted as a cause for failure.

The erroneous view is thinking one knows what lean is but breaking the principles of lean and neglecting organisational development for true lean. One key concern was breaking out of the ordinary day and giving time to continuous improvement. This would include setting aside tome to educate the managers and employees.

The researcher was involved in many of the daily struggles of implementing lean change including the ability of staff to handle change and ways to lead the staff. This necessitated the application of novel thinking to plan the approach and implement lean according to the many situational variables–product type and management and staff attitudes. The outcome was:

- The researcher gained a deeper practical understanding of the challenges faced in lean implementation.
- The importance or risks of method selection were highlighted for organisational development.
- A qualitative risk management approach was developed to assist in evaluating risk in a lean implementation.

These insights from industry embedment were developed and incorporated in the research hypotheses. Particularly developed is the aspect of lean knowledge or lean learning for success. This is discussed in detail in the next section.

4.3 Critique of Lean in New Zealand

4.3.1 Knowledge Gap in New Zealand

The contextualisation study highlighted areas of leadership understanding, management knowledge, and their impact on lean success. The literature review suggests there is knowledge about lean sustainability and that the proof of lean benefits is wide spread. Lean benefits are advertised in manufacturing and service industries, even in the health sector. Although more work is needed, basic knowledge on how to have a sustained implementation, and what is true lean, has been available in book form for nearly a decade (J. P. Womack & Jones, 2003; Liker, 2004) as well as through the rise of many internet resources (LEI, 2011).

The question that continued to be raised was:

> Why do managers in New Zealand and elsewhere (1) not embark on or (2) embark on a substandard, tool focused, and unsustainable lean implementations?

It is believed that the primary answer is simple: inadequate knowledge. The literature on information sources touches this (p. 64). The concern is:

> Passivity among senior managers towards acquiring new knowledge is particularly seen in the New Zealand.

This concern has also been raised and highlighted by others (Murti, 2009; Gardiner, 2011; Joiner, 2011; Reaney, 2011). A possible source for this is cultural. A typical expression in New Zealand is “she’ll be right” indicating a “can do” attitude that is positive in the sense of in applying creativity to find a solution or determination. However, it also tends towards lethargy or lack of interest for seeking out the truth. Another possible reason for passivity may have to do with the way lean has developed over time; the similarities seen between lean and other methodologies may give senior managers an attitude of “we have seen it all before” and “it is just a rehash of JIT, TQM or other methodology”. Because of the similarities, particularly seen in the tools, it is easy to neglect the serious development lean has been through the last 20 years.

This is not helped by consultants who wielded merely a tool approach for years and left a trail of unstained instances of lean implementations. Further, it is believed that senior managers, not realising the full benefit of up-to-date lean thinking, respond slowly (if at all) with their own finances. Interview sources suggested that senior managers (often owner operators) feel they can continue as usual, picking and choosing tools that benefit. Unless supported by funding like that of the NZTE[75] these managers are not likely to invest in consulting and training (Murti, 2009). This then leaves the knowledge of an SME enterprise to stagnate.

[75] Some may only participate in NZTE lean courses in a political sense to show good face and access further funding and support for other NZTE initiatives.

Expansion on a "Manager's own knowledge"

The extent to which businesses, and in particular the business leaders or managers, own lean knowledge is a factor of the success or failure of an implementation. Managers own knowledge is defined here as *the knowledge by which a manager makes decisions regarding the strategic direction and development of a business*. This knowledge is gained by training and experience.

Initially managers need a proper and accurate knowledge of the benefits and applicability of lean in their business. This should in turn install a desire to learn more about lean and its implementation. This is a base level accomplished by addressing (1) lethargy or apathy generating the desire or willingness to learn more about lean in order to reap the benefits. The learning that follows begins to address (2) the basic understanding of lean. However, the difficulty is to further advance the knowledge of lean beyond a superficial appreciation of tools and methods to (2) an adequate knowledge of the strategic and cultural aspects of lean. This higher level of lean knowledge is required for the design of sustainable implementation.

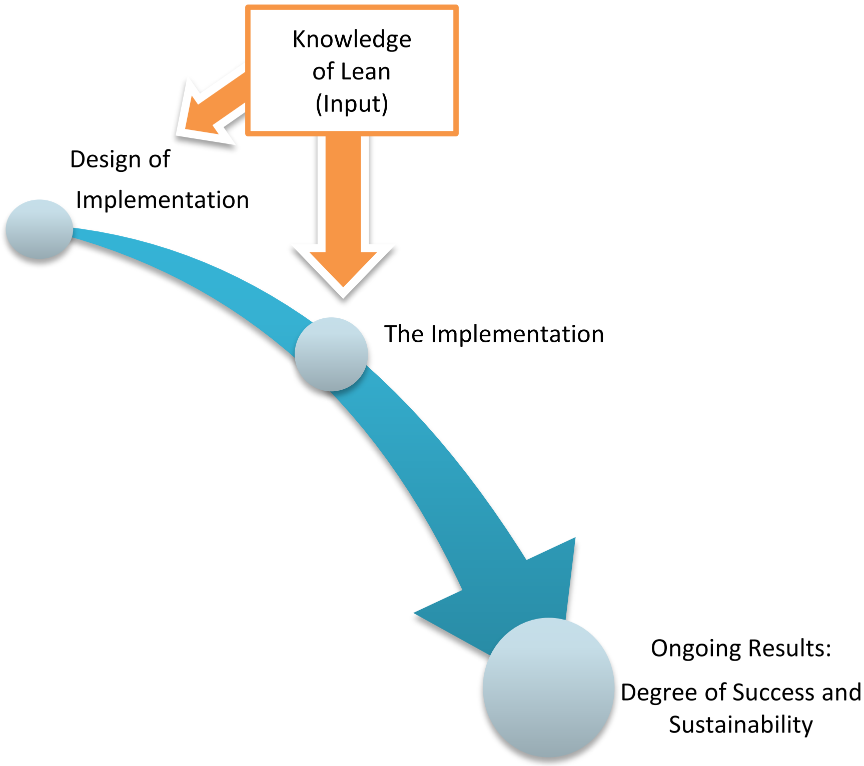


Figure 25 Lean knowledge, as an overriding success factor for lean. All aspects of implementation need this knowledge. (Image: A. Pearce)

Figure 25 illustrates an elementary concept; the results of a lean implementation are related to the knowledge of lean possessed by those designing and executing it. This is particularly true because of the customisation needed[76] with lean. The design and execution, including the way strategic and cultural aspects are handled, is

[76]A framework is also developed to assist with lean implementation design, i.e. specifically for small manufacturing businesses in New Zealand. This attempts to reduce the degree of customisation required and also serve as an example of such customisation.

based on this knowledge. Therefore, the level of success and sustainability are related to it. Thus lean knowledge was identified as a possible overriding or root cause success factor.

Model: Entrance of Lean Knowledge into the New Zealand SME

Here a model illustrates knowledge entrance into an SME. Figure 26 illustrates the understanding that the major entrance way for knowledge into such an organisation is through the openness and exposure of management to that information. Although new and motivated employees may bring in knowledge, along with a variety of other sources; the major entrance way would be through management. This was indicated by the large arrow. It is true that other employees may be trained to bring in knowledge but this is proposed to be typically the result of the employer, management recognising value in particular knowledge and hence still acting as the gate keeper for that knowledge entry.

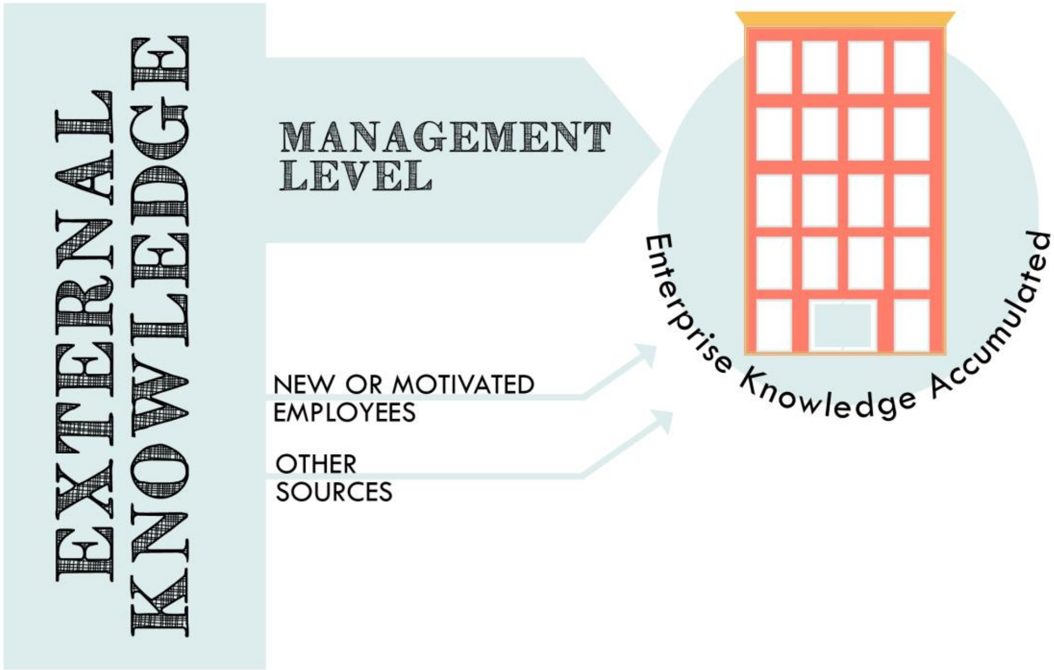


Figure 26 Entrance of knowledge into the typical New Zealand SME. Proposing that lean thinking enters predominantly through the management level. (Image: A. Pearce)

Large firms have systems and staff that, besides bringing knowledge, can be deployed to drive and sustain an implementation. How about SMEs? SMEs lack dedicated resource and in-house skill. These lack of resources are highlighted in the below practitioner comments[77] from a LinkedIn. These comments were made following a visit by Dr. Liker to New Zealand. Negatively, the comments show the struggles of resource

[77] Linked-In Discussion; Dr. Jeffrey K. Liker. University of Auckland Business School, http://www.linkedin.com, IP5 - NZ Lean Service Group, 15 Nov 2011

constrained small businesses. Positively, the discussion shows information sharing among practitioners to solve common problems.

> *The questions was "how do we apply his ideas and principles at a small company like ours with less than 50 people?" Forming a lean team of 10 people could pull a quarter of the workforce impacting on the ability to meet customer deliverables.*
>
> *The answer he provided was not that helpful, particularly when I asked for clarification and details. The suggestion was to identify a Lean Leader for the key teams, which is more or less what we are doing.*
>
> [Smith]
>
> ---
>
> *It's an interesting debate* [Smith]*, as we are finding the same in our small organisation. Deliverables to our clients always take priority and often our Kaisen team meeting is bumped, and so lean tends to fall off the agenda. One thing we are finding however, is that when we rotate and invite different team members to the meeting, we uncover very interesting ideas that they contribute, proving to be very valuable to the business.*
>
> --
>
> *I am particularly interested in small-enterprise lean at the moment. I am quite addicted to continuous improvement so tend to put a high emphasis on spending time developing new systems and now staff. It is hard to know where to draw the line. We have about 20 staff and a lot of potential business swinging our way in the near future. So I ask myself, how much time do I spend on turning over the opportunities and how much time do you spend developing systems and personnel so you can up throughput to handle more of the opportunities in the future? The natural thing is to put your head down and pump out as much work as you can (make hay while the sun shines) but that doesn't help you go forward or be realigned for when the "sun stops shining".*
>
> --
>
> *Our challenge in small business is that the same principles apply as if it were a large business i.e. financial, marketing, strategy, quality, lean management etc but the resources and therefore approach is different. As CEO I am able to prioritise and lead various discrete projects e.g. currently we have three priorities of which Lean Mananagement is one. It would be nice to have a dedicated owner of each of these disciplines however we address each one in a more flexible way e.g. our approach is that over a period of say 24 months we do a deep look at each discipline according to cost / benefit prioritries. Looking forward to more discussion on this topic on Wednesday.*

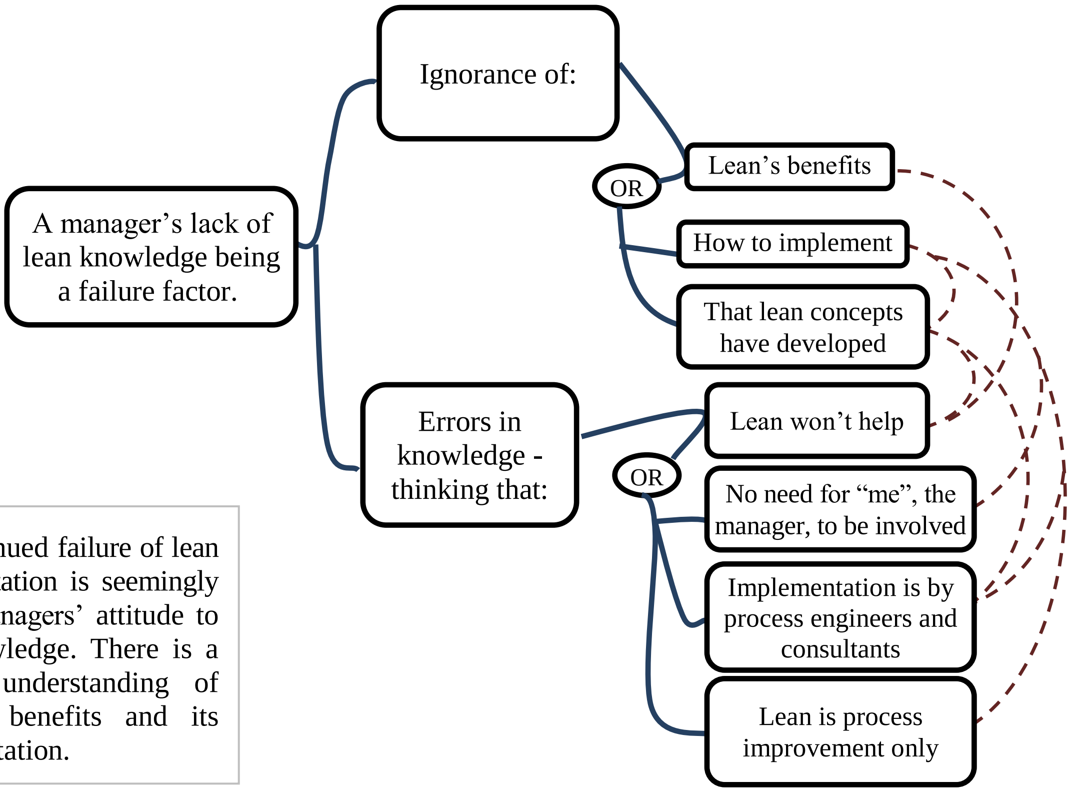
Staff attrition worsens the situation for SMEs. Employee training allows their skills to be developed but there is less incentive to train staff in an SME. This is because trained staffs quickly move on to opportunities in larger firms and the knowledge leaves the SME (Goodyer et al., 2011). This includes the knowledge gained by both learning and the experience within the particular setting of an organisation. This kind of tactile knowledge is difficult to codify (store for others reference). However to retain this knowledge is particularly crucial in lean implementations; there is not a plethora of models for how to implement lean in different settings. For example, there is not a model particularly for implementation of lean in a precision CNC machining SME supplying medical industry in New Zealand. Only broad principles as discussed in this text are available. Hence, lean systems are developed to suit the operating characteristics and culture of an organisation. The extent of documentation required to codify such tactile knowledge is enormous and likely overwhelming to achieve in an SME, however also potentially devastating to enterprise efficacy if the knowledge leaves with a staff member.

The model presented (Figure 26) may be posed for other businesses beyond New Zealand and to SME's globally. However, in light of the above discussion it is believed this model is especially relevant in New Zealand because of the small size of New Zealand manufacturing firms. SME size is particularly small in New Zealand i.e. up to 19 employees as determined by the Ministry of Economic Development in NZ (Goodyer et al., 2011). Typically, an SME of this size would be owner operated. It is strongly believed that management in such a business is a key entrance point of knowledge and their exposure and openness to lean information sources would dramatically affect the initiation and success of lean implementation.

Ignorance and Errors in Management Knowledge

This research proposes that ignorance and error in managers' knowledge is a serious failure factor that needs to be addressed in SMEs. This was particularly developed during the analysis of New Zealand's case and needs, regarding lean sustainability.

The effects of management knowledge and understanding are conceptualised in Figure 27. The figure implies first, that managers' ignorance of lean's benefits causes them to neglect lean and not focus on lean as a strategic priority. Second, they may know of the benefits but may not have adequate knowledge to implement lean. Third, managers' may have knowledge of lean but it may be out of date, neglecting it because they do not have the developed understanding. Fourth, there may be errors in knowledge that lean won't help their particular case; thinking lean is just for mass production. The final points are related to how an implementation is executed. That is, Fifth, managers' not realising that they must be involved. Sixth, they delegate the implementation to process engineers and consultants. Finally, managers' may think of lean as only process improvement, seeing it as tools and techniques but not a culture with employee engagement. A manager's lack of knowledge was proposed as an overriding failure factor for lean implementation.



The continued failure of lean implementation is seemingly due to managers' attitude to lean knowledge. There is a lack of understanding of lean, its benefits and its implementation.

Figure 27 A manager's lack of knowledge is a possible overriding failure factor for lean implementation. Here the knowledge lack is described as a function of ignorance and error in a manager's understanding. (Image: A. Pearce)

4.3.2 Capability for Lean Implementation

Since knowledge was seen as important, the question of competence and ability was raised. That is firstly, how important is the calibre of a manager to the success of implementation? And secondly, how important is the calibre of staff to the success and sustainability of Lean?

Other questions follow: *Can any manager or business owner function for successful change or is there a special requirement? Is it better that the owner in the SME situation be the change agent or just give committed support? How much does the change agent's capability affect the success of a lean implementation?*

Besides this, management commitment is observed to be a success factor but how can a manager commit to something they don't understand. Surely, an adequate understanding of lean is a prerequisite for proper commitment. If a manger thinks about lean as tools and processes to be carried out by delegated staff or a selected consultant that is what he commits to; this is inadequate for successful change.

4.4 Contextualisation Study Outcomes

The contextualisation study identified issues for lean implementation in New Zealand and gave the research practical grounding in industry.

The practical experience and investigation of past and present New Zealand practice was essential to targeting the real problems in industry.

> The research was grounded in reality through the review of others' experiences and first hand application of change leadership in a real world setting.

The outcome of this was observed in the development of the research hypotheses concurrent with literature review as discussed below.

4.4.1 Leadership, Lean Knowledge and Capability (Hypothesis 1 and Hypothesis 2)

Industry embedment underlined the necessity of developing lean knowledge. The challenge faced necessitated particular skill and application of organisational leadership and lean techniques and education. Knowledge became the wisdom needed to handle the many challenges of leading implementation. Others lack of knowledge was highlighted as a key hindrance to success, a failure factor. Managers' knowledge is defined here as *the knowledge by which a manager makes decisions regarding the strategic direction and development of a business*. This knowledge is gained by training and experience. These outcomes are summarised:

> By comparing Case A with Case B, the positive effects of lean knowledge were seen. Knowledge developed into skills for implementing change. Alternatively, low knowledge and a poor understanding of lean were highlighted as a cause for failure.

These points all strengthened the forming of Hypothesis 1:

> ***Hypothesis 1: The major success and failure factor for lean is leadership knowledge.***

The more technical aspects and use of consultants were thought to be secondary to success. Leadership in general was considered to be most important, but specifically enabling the development of employees through supporting them and their initiatives. This is seen in Hypothesis 2.

> ***Hypothesis 2: Consultants and the tools or methods of lean are secondary. The primary aspects are leadership and enabling development.***

This did issue in a second question:

> How important is the capability of managers, staff, and consultants to the success and sustainability of lean?

This is not explicitly covered as a hypothesis but a research question to be explored.

4.4.2 Management Attitude to Lean (Hypothesis 4)

The background work identified lean as being worthwhile to pursue in New Zealand. Successful cases did exist in New Zealand from early on (Toyota Thames and Fisher & Paykel both adapted their own version of lean successfully).

Unfortunately, lack of lean knowledge in New Zealand was pointed to by the review and observed during industry embedment. It is believed that managers in New Zealand are indifferent (lethargic) towards contemporary lean thinking due to national characteristics, prior experience, and erroneous knowledge. Such knowledge leads to no or inadequate implementations of lean. The discussions lead to the role of management as the entrance gate for knowledge in the business and advanced to the question of staff and management capability. The need for management knowledge of lean was developed as a core part of this work. Here it is summarised:

> The uptake of lean has been slow with little penetration of lean knowledge (especially up to the start of the NZTE program).

The concern is that:

> Passivity among senior managers towards acquiring new knowledge is particularly seen in New Zealand.

Even now, it is unclear how many of the managers that take the NZTE lean courses really connect with or commit to true lean.

These insights are captured in Hypothesis 4:

> ***Hypothesis 4: New Zealand's senior managers (represented largely by those in SMEs) have been slow to pick up lean management.***

4.4.3 Model Supporting SMEs

The struggles faced by the SMEs to gain the adequate knowledge, and develop lean capability were also discussed. It was recognised that:

> SMEs lack dedicated resource and in-house skill for the complications of lean change.
> SMEs do have specific needs and challenges different to those of larger businesses, i.e. situationally specific success factors.

Hence the importance of defining the key aspects of lean for SMEs in an easily understandable form.

4.4.4 Hinged in Success Factors (Hypothesis 3)

Ultimately, this research hinges in the belief that although situations are different it is believed key success factors are common.

> ***Hypothesis 3: The key success factors for lean do not differ due to business size, and product mix.***

For this work, the key factors for implementation have been identified from the literature such that models of correlation and causality could be built; this can form a base for future practitioner models.

4.4.5 Risk Management—Decision Making Process

A step towards practitioner models was made as an outcome of Case C. That is, the importance or risk of method selection was highlighted for organisational development. And an outcome of this was:

> A qualitative risk management approach was developed to assist with decision making in lean.

The risk map can be used for assessing the tools and also communicating the challenges of implementation.

Lean implementation is essentially a process of decision making. The many failed instances of lean emphasise the risk of failure indicating threats to success. The extreme positive outcomes from other implementations show the benefits of lean. It remains to be proven whether a structured method, as developed in Case C, is necessary. However, whether formal or informal, leadership decision making needs to address *risk management* to mitigate the risk of failure (threats) and maximise opportunities of success for success (benefits) during lean implementation.

4.4.6 Limitations

The review of lean in New Zealand satisfied its purpose and filled some gaps of undocumented lean history. However, a larger number of interview sources would have been advantageous.

The contextualisation study helped form the hypotheses but it was not for testing them. The second case study (case B), considered a knowledge-based experiment, was relatively short (12 months) and only two industries were involved in the embedment (precision engineering and construction SMEs). And the case study for the lean risk assessment was cross sectional. Multiple posterior case studies could further validate findings over time.

4.4.7 Outcome

The contextualisation study identified issues for lean implementation in New Zealand and gave the research practical grounding in industry. The practical experience and investigation was essential to targeting the real problems. The practical ground was accomplished with the first hand application of change leadership (struggling with the challenges of implementation) and discussion with other practitioners (learning of the challenges they faced). This work was concurrent with the literature review and strongly influenced the research hypotheses. A practical outcome was the qualitative risk approach to implementation.

5. Development of Conceptual Frameworks

The purpose of this work was to identify and explore lean success factors. This included the extent to which a manager's own knowledge impacts the success or failure of an implementation. This was a worthwhile exercise because of its potential to enhance productivity and the commercial success of New Zealand industries through successful lean implementations.

To systematise the developed understanding of lean implementation a tentative framework was produced. This framework set groundwork for the questionnaire experiments.

5.1 Tentative Framework

The tentative framework for lean implementation is below, Figure 28; it integrated the outcomes of the literature review and contextualisation study(pp. 72, 130). In the framework many key factors are mentioned but practically no causal relationships are represented. The purpose of this model was to give a general overview of implementation. Causal relationships were hypothesised and tested as part of the structural equation modelling.

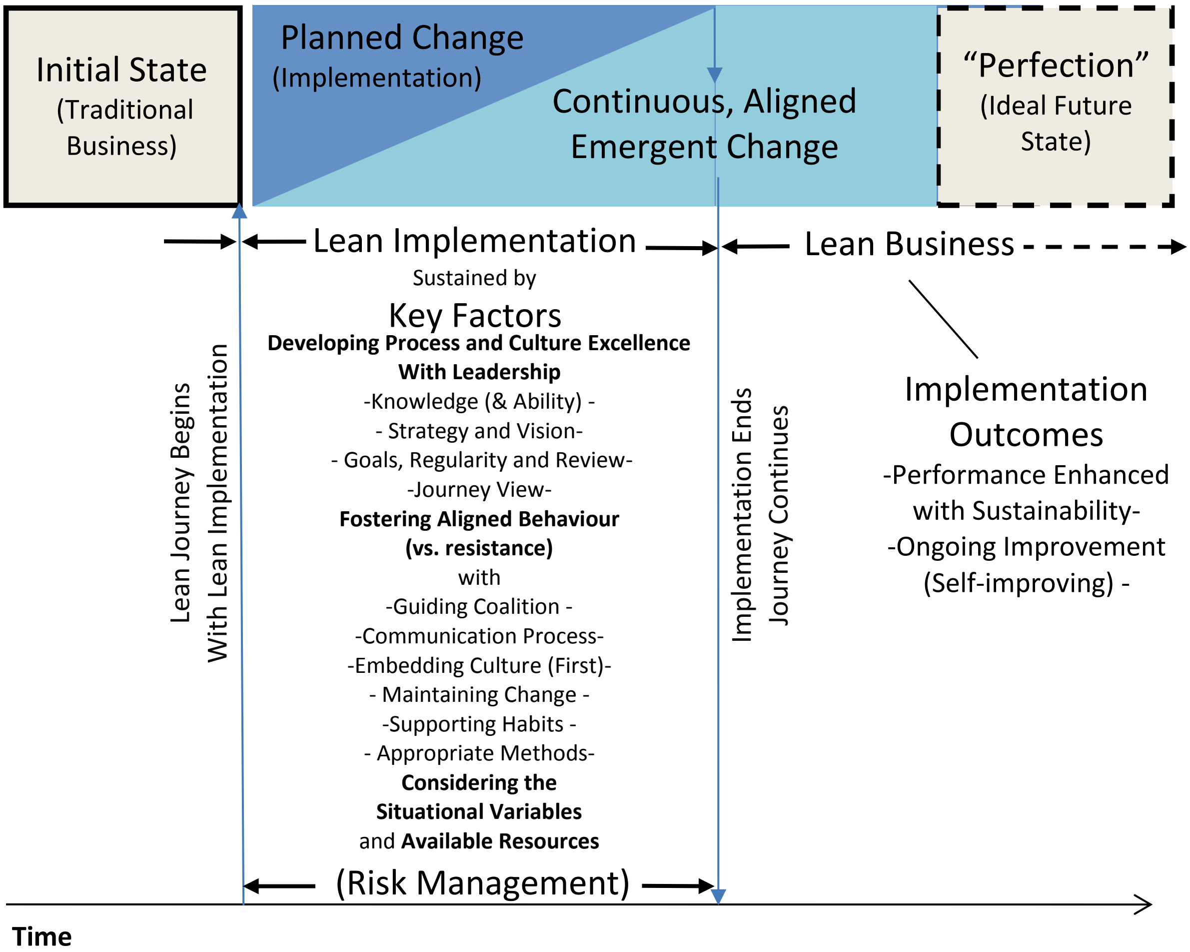


Figure 28 A tentative framework for lean implementation. The framework gives an overview of the change and identifies key factors. (Image: A. Pearce)

The framework shows a business transitioning on an axis of time. The transition is from a present to a future state. The transition is the lean implementation, a planned change that has the purpose of developing more emergent change within the organisation. The decreasing and increasing wedges indicate a change in focus as time goes on. Initially change is driven by managements' planning, ultimately, change is emerging from all levels of the business as represented by the bottom wedge. At this state, a lean business is operating and the emergent change is driving the organisation to perfection; it is maintaining continuous improvement.

5.1.1 Key Factors for Implementation

The framework identifies many key factors for the implementation. Of the factors, leadership is believed to play the critical role in implementation. Leadership is responsible for setting the strategy and vision that they can align the organisation. This includes setting goals, providing the regularity, and reviewing progress. As continuous improvement implies, there is the need for a view of an on-going journey of change. Throughout the change, leadership can foster the behaviours of staff, and overcome resistance to change. Key supporting matters were developing a guiding coalition, establishing a communication process, embedding the culture, maintaining the change, and supporting the proper habits in the environment and processes. However, implementation success does not neglect the proper use of lean methods, it needs proper consideration of the situational variables, recognition of the available resources, and other miscellaneous factors. These key factors are discussed in this chapter. They are captured in the questions for the survey experiments.

5.1.2 Risk Management

The model also labels the lean implementation band as a zone of risk management. Leaderships' development of process and culture excellence, fostering aligned staff behaviours requires appropriate leverage of the critical success factors. This is accomplished within the context of the specific organisation, considering the situational variables and available resources. This implementation process, from a leadership perspective, is a decision making exercise of risk management. Leadership decision making needs to maximise opportunities (benefits) and minimise detriments (threats) for successful implementation.

5.1.3 Planned versus Continuous Emergent Change

The literature on organisational change was vast and sometimes disjointed. To support the understanding of planned and continuous change a model was developed (Figure 29). The model shows the two ends of the scale of change. At one end is a coercive top-down planned approach from management. At the other end is a culture-excellent emergent change approach, where change emerges from all levels.

Change is properly viewed as something that is endogenously emerging. However many take a top-down planned approach as shown on the left hand side. This approach is where senior management hold the vision and drive the change that they see fit to the organisation. They typically use coercion to overcome resistance to change from employees at other levels. This may be suitable for slow changing bureaucratic organisations (if that is ever desirable).

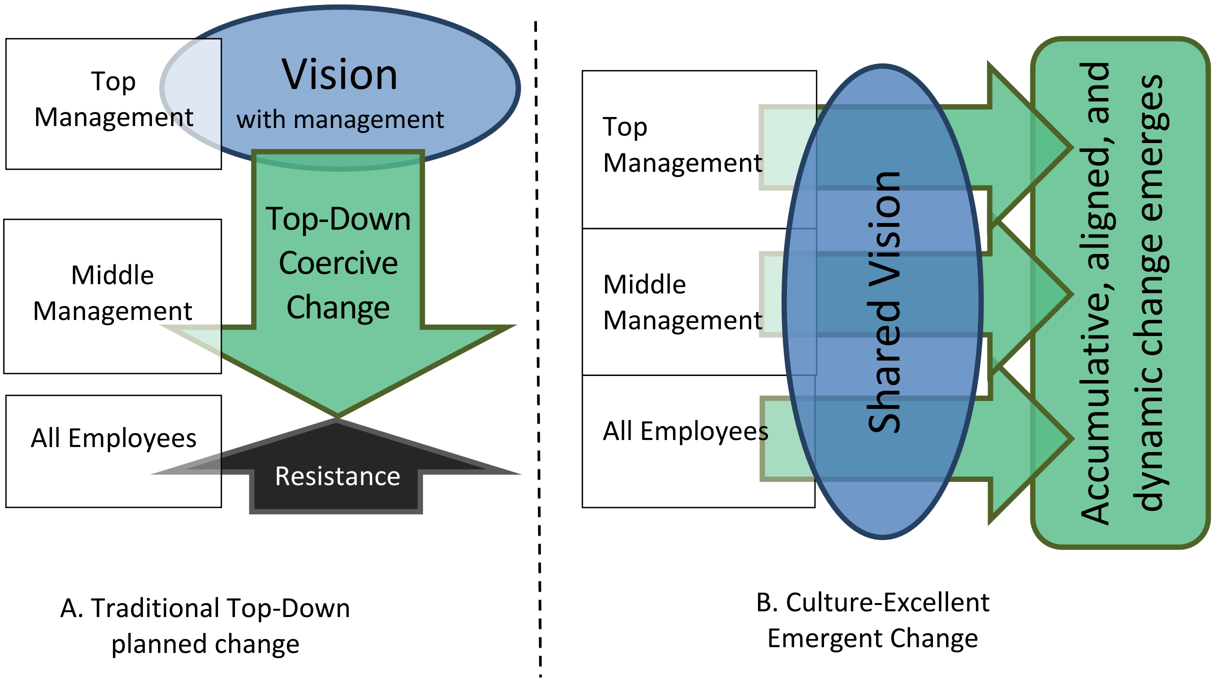


Figure 29 Traditional Top-Down Change compared with Culture-Excellent Emergent Change.

Culture-excellent emergent change has a shared vision and gives all levels of hierarchy the ability to instigate change. This requires culture-excellence and is dynamic and powerful with the accumulation of change. The top-down approach is slower, more static, and requires coercion for change. (Image: A. Pearce)

The preferred approach is the culture excellent-emergent change model as depicted on the right hand side. This shows a vision that has been shared with all staff, that sets basic rules of operation, and aligns staff initiatives to the goals of the organisation. In this model, management values the contribution of all employees to the development of the company. The result is accumulated aligned change emerging at all levels, rather than a top-down change resisted by the lower levels and requiring coercive treatment.

A lean implementation can be framed in organisational development terms. This helps develop the understanding of lean and the key questions that need to be addressed.

5.1.4 Lean Implementation: Planned Change for Emergent Change

Lean implementation involves a transformation. Its purpose is to produce sustained continuous improvement, with the culture excellence sought after by emergent change proponents (Burnes, 2005; Sashkin & Burke, 1987; Tsoukas & Chia, 2002; K.E. Weick & Quinn, 1999). Much of the benefit or power of a lean business is attributed to its becoming this kind of dynamic, learning organisation (Hines et al., 2008; Liker, 2004). In such an organisation culture is cash and a true defendable competitive advantage (Spence, 2012). This is the way that a company moves towards the goal of perfection (Ohno, 1988; J. P. Womack & Jones, 1996).

The initial implementation of lean is typically top-down, lead from a management level. Management typically makes a decision[78] "As management we need to do something about performance". However, the ideal future state is when an organisation is daily led by the "floor" and perpetually improves the organisation. That is, lean's respect for humans principle suggests that the factory floor, the "gemba" or place of work, is where change should be driven from (Ohno, 1988).

If bureaucratic force is required to maintain the change then it is not successful in this context and in fact is not lean in nature even if the tools or methods of lean are in place.

These changes should still be aligned with the strategic objectives and direction from management (Hines et al., 2008). It is recognised that some major changes, like strategic manufacturing decisions, are more likely to be initiated from a higher level in the organisation, for example changing a facility from operating as batch and queue to operating with one-piece flow just-in-time would occur from higher up. Hence, true lean implementation is a change that is planned from the top-down with the goal of producing continuous emergent change from all levels.

A planned change intervention can be used to overcome existing inertia (K.E. Weick & Quinn, 1999). In this way a planned change can be used to open up possibilities for on-going improvement (some which are anticipated and some which are not) (Tsoukas & Chia, 2002). The unanticipated changes are the results of enabling emergent change. This was seen in the Navy's introduction of *total quality management*, where suggestions from junior officers were finally recognised (Tsoukas & Chia, 2002; ref. Barrett, Thomas, & Hocevar, 1995). This was a planned change for TQM that facilitated emergent change.

> Hence, a lean implementation is then characterised by a shift from an initial top-down change to the developing of an organisation of emergent change. This is in the respect for humans principle and points to real kaizen.

In this work, preference is given to "emergent" change rather than "bottom-up" change. This is to clarify the difference between bottom-up and emergent. Traditional top-down approaches have limited effectiveness and bottom-up change is considered powerful. However, leadership is still necessary; at times, change should be initiated from the top levels. This is particularly due to a strategic overview and company direction possessed by senior management. Thus, *emergent* is used as an inclusive term that represents change coming from all levels, not top-down, not-bottom up but from all levels.

[78] This kind of decision may be prompted by a lower level but is logical to assume that it will need recognition from a management level of some kind for a widespread change to occur. This is specifically as the research focuses to the SME context.

Implications to Questionnaire

Emergent change implies that the respect for people principle is understood, which includes staff development through training and empowerment. The following questions were included in questionnaire One:

(V054) Do the following statements match your understanding of lean? [Lean gives workers training and empowerment to solve problems.]

(V057) Do the following statements match your understanding of lean? [Lean means respecting people.]

The goal of implementation is to develop a learning organisation. This kind of transformation indicates a major change in the business philosophy.

(V092) To what extent would the following be relevant to your organisation? [Becoming a Lean Learning Organisation]

(V058) Do the following statements match your understanding of lean? [The implementation of a company wide philosophy and strategy.]

Management force being used to freeze change is seen as a negative aspect of a planned change. This negative aspect was reviewed in questionnaire One:

(V073) Do you agree the following are crucial in the initial stage (year) of lean implementation [Management to enforce the best practices to freeze changes.]

On the positive side of emergent change is communication with all staff and staff alignment with the business goals. Hence:

(V078) To what extent would the following be relevant to your organisation? [Staff alignment with strategy.]

(V069) Do you agree the following are crucial in the initial stage (year) of lean implementation? [Develop an effective communication process]

These questions added to questionnaire One, did not cover all the factors but identified key aspects.

In questionnaire two, many factors of emergent change were covered. From an emergent view, involvement of all staff is logical. And to engage the staff from early on in the implementation is seen as important. These are captured below:

(V057) How much do you agree that management...? [Involved all staff]

(V039) Answer to what extent the implementation... [involved and was communicated to the staff in the planning stage]

(V041) Answer to what extent the implementation... [encourages, facilitates, and involves worker improvement initiatives]

(V048) How much do you agree that management...? [made it easy for staff to suggest and accomplish improvements]

The planned aspect of the change will necessarily require just that, planning. This typically would involve developing the vision and approach.

(V047) How much do you agree that management...? [planned well for the implementation]

An effective communication process is needed to align the initiatives and engage staff.

(V050) How much do you agree that management...? [used an effective communication process]

(V051) How much do you agree that management...? [clearly and vividly communicated to staff the company strategy/vision]

(V052) How much do you agree that management...? [clearly and vividly communicated how staff roles and initiatives aligned with strategy]

For high levels of communication, a flat structure has been viewed as beneficial.

(V029) Is the company's structure relatively flat?

The extent and type of management involvement is a key part of change. Management may become overburdened trying to force changes rather than engaging staff. This is not believed to be a sustainable model and is against emergent change for continuous improvement. These thoughts were investigated as:

(V060) How much do you agree that management...? [pressure was needed to enforce the desired behaviour changes.]

(V061) How much do you agree that management...? [pressure is still needed for staff to maintain the lean behaviours.]

Much of this speaks to whether lean was viewed as a culture and philosophy or purely a process improvement initiative by tools.

(V068) Answer to what extent... [Management understood implementation as a new culture/philosophy.]

(V037) Answer to what extent the implementation... [emphasised a new culture]

(V038) Answer to what extent the implementation... [actually developed a new culture]

5.2 Implementation Outcome—Success and Sustainability

The specific context of this study is how practitioners[79] can achieve success and avoid failure. In lean, one could stipulate that a successful lean exercise is one that reduces waste. This research views true success as

[79] Particularly New Zealand managers desiring to implement Lean for the first time in their small businesses.

sustained change with continuous improvement towards perfection; it has no interest in the success of lean as a one-off of exercise, or kaikaku[80] initiative.

Implications to Questionnaire

In the knowledge survey, the perceived outcomes for lean were expressed in terms of competitive advantage.

(V062) To what extent does Lean provide a competitive advantage?

The extent to which lean results in a different business model was also addressed.

(V058) Do the following statements match your understanding of lean? [The implementation of a company wide philosophy and strategy.]

(V092) To what extent would the following be relevant to your organisation? [Becoming a Lean Learning Organisation]

In questionnaire One it was pointless to ask whether it is desirable to sustain process improvement initiatives.

In questionnaire Two, implementation outcomes were assessed in multiple ways. Feedback from the first experiment showed that lean was perceived by some as an essential part of a business, and therefore not a competitive advantage. Thus an additional performance assessment was needed.

(V015) Has the implementation provided a competitive advantage?

(V016) Has business performance improved?

These two questions (and many others) were accompanied by a text response box for participants to provide clarification.

Besides performance, an assessment of permeability was required, i.e. had the implementation sustained. Further to this, an indication of whether continuous improvement had been embedded in the company culture was required.

(V040) Answer to what extent the implementation... [has been sustained]

(V044) Answer to what extent the implementation... [developed a self-improving organisation]

A change in company culture was also captured:

(V037) Answer to what extent the implementation... [emphasised a new culture]

(V038) Answer to what extent the implementation... [actually developed a new culture]

Although increased staff morale does not explicitly imply increased performance or sustainability, the contextualisation study identified it as a related factor.

(V017) Has staff (employee) morale increased since implementation?

[80] Kaizen refers to continuous and gradual improvements whereas Kaikaku refers to radical change.

A litmus test for the sustainability of the change was also provided; that is, whether or not the changes were self-sustaining or driven by management pressure.

(V061) How much do you agree that management...? [pressure is still needed for staff to maintain the lean behaviours.]

To test whether that much change was needed in the first place, the following question was asked.

(V103) Rate the following. [Did a culture similar or conducive to the desired culture already exist?]

Besides general comment boxes, two specific questions addressed the significant negative and positive outcomes.

(V109) What were significant positive outcomes for the organisation?

(V110) Were there significant negative outcomes? (List if any)

A good coverage of outcomes was achieved.

5.2.1 Culture Excellence and Process Excellence for Operational Excellence

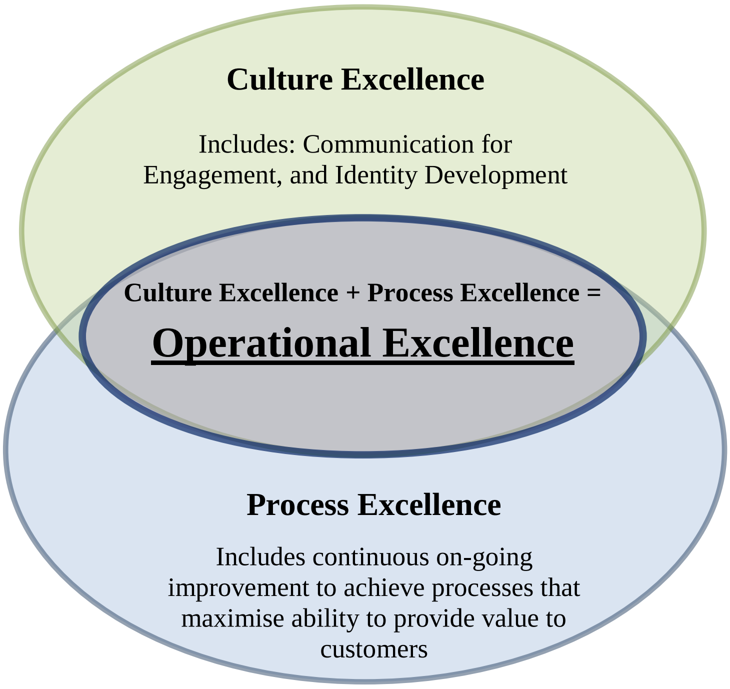


Figure 30 Culture excellence and process excellence combined for operational excellence.

It is unfortunate that process excellence is usually focused on while culture excellence is neglected and the goal of operational excellence is not achieved.

In reality lean is for achieving an outcome of operational-excellence. For this, two complimentary things are needed. On one hand, there is the development of the systems and processes for improving the way work is done. This has been coined here as achieving process-excellence. On the other hand is culture-excellence, which is not seen so easily. This more hidden aspect may not be critical for initial gains but has been associated with on-going success. The conceptual understanding is briefly summarised[81] in the Venn diagram for operational-excellence, Figure 30.

Implications to Questionnaire

Experiment One surveyed how participants understood lean. Questions asked slight variants on the similar themes. Most of these individual variables were based on a common question:

Do the following statements match your understanding of lean?

Some questions were process related.

(V051) [Lean implementation is of tools and processes for improving productivity.]

(V052) [Lean is tools or methods primarily for process or industrial engineers.]

(V053) [Lean means eliminating waste.]

(V056) [Lean is implementation of new systems and ways of doing things to improve productivity.]

(V060) [Lean is a new label for industrial engineering and the work of industrial engineers.]

And others were culture related.

(V054) [Lean gives workers training and empowerment to solve problems.]

(V057) [Lean means respecting people.]

(V058) [The implementation of a company wide philosophy and strategy.]

Additional from this question set were:

(V068) Do you agree the following are crucial in the initial stage (year) of Lean implementation? [Learning the best improvement methods]

(V074) Do you agree the following are crucial in the initial stage (year) of Lean implementation? [Implement new technology.]

As well as the relevance of lean accounting processes.

(V094) To what extent would the following be relevant to your organisation? [Flow/Lean accounting]

Other questions addressed the approach for implementation, e.g. small and regular wins (V071) as opposed to large impact events (V067). Some lean methods are also used for developing the right culture and behaviour; these include a communication process (V069) like nemawashi or A3 management (V081), visual systems (V091), and standard work (V095).

[81] Both summarises the content and present alternative terminology for the concepts already in this work.

For questionnaire Two, the most direct questioning regarding processes was:

(V034) Answer to what extent the implementation... [emphasised process improvement, methods or tools]

The extent to which key principles of lean featured was also asked.

(V059) How much do you agree that management...? [focused on improving flow rather than utilisation of people and equipment]

(V093) How much were the following a feature of the implementation? [Defining Value]

(V094) How much were the following a feature of the implementation? [Pull Systems]

(V097) How much were the following a feature of the implementation? [Mapping of the value stream]

Further questions were asked about the methods.

How much were the following a feature of the implementation?

(V085) [Advanced Information Systems (MRP, ERP, other)]

(V086) [5S System]

(V087) [Just In Time Manufacture]

(V088) [A3 Management or Nemawashi or Catchball process]

(V089) [Total Productive Maintenance]

(V090) [Kaizen (Kaikaku) Improvement Events]

(V091) [5 Whys]

(V095) [Kanban]

(V096) [Used statistical methods]

(V098) [Visual Systems]

Simple problem solving and root cause analysis were investigated.

(V092) How much where the following a feature of the implementation? [Used and trained staff in simple problem solving.]

(V099) How much where the following a feature of the implementation? [Root Cause Analysis][82]

[82] See also 5 Whys method (above). A tool for simple problem solving with root-cause analysis.

Reaching beyond the internal processes to engage with customers and suppliers was also included.

(V100) How much where the following a feature of the implementation? [Engaging suppliers]

(V101) How much where the following a feature of the implementation? [Engaging customers]

By all the above questions key lean processes and methods were included in the study.

5.3 Leadership

Successful change requires leadership leading change, not merely managing it. Leadership is not presenting the big picture and taking the hands off. That kind of inappropriate delegation does not work; people need to be led through the details. Leaders need to provide clear direction for the critical steps of change. Employees need the vision is to be presented along with the next critical step. This is part of on-going vision setting, strategy, and deployment. Leaders need to coach employees through change and gain the trust of staff.

Implications to Questionnaire

Experiment One focused on leadership knowledge, see *Knowledge and Capability* (p. 144). It also addressed leadership's view of lean as a philosophy and business strategy (V058).

Regarding experiment Two, implementation leadership is somewhat all inclusive. However, a key factor for leadership is their commitment. Additional to their personal commitment, a good rapport with employees is needed.

(V036) Answer to what extent the implementation... [was committed to by management]

(V056) How much do you agree that management...? [had the trust of staff]

Experiment Two addressed what managers actually did. The commitment of managers could be measured in different ways. Two additional way it was measured were, how much the managers committed to training (V054) and continued to learn and participation (V105).

Regarding leading individuals in change, the question was asked:

(V079) Answer to what extent… [Staff received individual support in adjusting to the change.]

Additionally, leadership tends to go together with communication for employee alignment. Participants were asked how much management used an effective communication process (V050), clearly and vividly communicated to staff the company strategy/vision (V051), clearly and vividly communicated how staff roles and initiatives aligned with strategy (V052), and communicated the specific steps of change clearly (V053). Using fear (e.g. job loss) as a motivational technique was also included (V071).

5.3.1 Knowledge and Capability

It is necessary to consider the effect of lean knowledge and capability required for lean implementation. Education and training of staff is part of the communication process for engagement and understanding, as well as equipping with appropriate skills for operating new systems and problem solving. The knowledge needs to start with management. This was embodied in Hypothesis 1:

> ***Hypothesis 1: The major success and failure factor for lean is leadership knowledge.***

It is believed education of the managers implementing change is of highest importance. Ackerman (1986) referencing transformational change said *"training executives to lead this kind of change is not a simple task and does not end in the classroom".* A strong link between the amount of lean knowledge and the appropriate attention to success factors was expected.

Implications to Questionnaire

Experiment One focused on lean knowledge. It took two measure, familiarity with lean (i.e. understanding lean) and experience in implementation.

(V098) To what extent are you familiar with the following? [Lean and/or the TPS (or variation of e.g. ACE, Lean Health etc.)]

(V106) To what extent have you implemented the following? [Lean and/or the TPS (or variation of e.g. ACE, Lean Health etc.)]

The responses to these questions could be used as the key independent variables. A key comparison was to be made with the competitive advantage variable to see how lean knowledge affects the advantages that are perceived.

Additional question assessed the knowledge and experience with other methodologies as well as participants training and years of work experience. Drivers for gaining lean knowledge were also assessed. Participants with moderate or lower levels of lean familiarity were asked:

(V041) We want to assess the reason people do or do not seek out more knowledge of the systems (particularly lean). We would appreciate any reasons why you have not obtained further knowledge of lean. Example: You may believe it is not important for your position to have the advanced knowledge or that lean is not relevant to your industry or you have no time or are simply unaware of its existence.

Participants with above moderate levels of lean familiarity were asked:

(V042) We want to assess the reason people do or do not seek out more knowledge of the systems (particularly Lean). What made you seek out or learn about lean? Example: You may believe it is important for your position to have the advanced knowledge or been forced to in your job.

Regarding importance of management knowledge and commitment to learning two parts of one questions were asked:

Lean is an organisational change. Do you agree with the following statements?

(V064) The extent that a manager understands lean and lean implementation is critical for the success of lean. Understanding what is critical governs their decision-making, ensuring greater chances of success.

(V065) In a small organisation (say less than 50 staff) the management's understanding of lean should be the first and top priority to ensure an implementation is handled properly.

The second question (V065) is directed at SMEs and purposefully has a stronger tone it. The survey specifically left space for text responses to this question.

Experiment Two, also addressed the managers' knowledge of lean generally and their knowledge of the methods specifically.

(V055) How much do you agree that management...? [had excellent knowledge of lean]

(V067) Answer to what extent… [management understood the tools and methods for improvement.]

The questionnaire further addressed their understanding of lean in a holistic sense as a culture and philosophy i.e. as opposed to knowing the methods.

(V068) Answer to what extent… [Management understood implementation as a new culture/philosophy.]

The questionnaire assessed management's initial level of lean knowledge at the beginning of the implementation as well as attitude to learning throughout the implementation.

(V106) Rate the following. [At the start of the implementation did management establish (or have) a sound knowledge of lean?]

(V105) Rate the following… [Did management continue to learn and participate throughout implementation?]

The participant were also asked their years of work experience (V007) and their experience with different methodologies (V008 –V012).

Leadership Capability

Discussion of lean knowledge led to the question of capability. Leadership capability from the managers' side was assessed through the knowledge questions and also directly as below.

(V064) What is your estimation of the competence, capability, and calibre of the company's...? [Management]

Aspects of leadership were expected to rank highly in the analysis. Many questions on the specifics of management investigated the concept of leadership commitment.

5.4 Implementation Factors

From the review of literature on lean and organisational change, key factors for implementation were identified. These factors are mainly explored in experiment Two, the implementation case studies.

5.4.1 Strategy and Vision

Strategy and vision need to be developed and imparted to employees for their alignment. The vision given by leadership should find feeling, motivating the employees' emotion and not merely present analytical arguments and facts. An urgency to change needs to be established however, fear should be avoided.

The aspects of planning as well as strategy and vision were captured.

(V047) How much do you agree that management...? [planned well for the implementation]

(V051) How much do you agree that management...? [clearly and vividly communicated to staff the company strategy/vision]

Alignment of staff role with the strategy was addressed:

(V052) How much do you agree that management...? [clearly and vividly communicated how staff roles and initiatives aligned with strategy]

Other questions gave similar insights e.g. staff involvement in planning (V039) and the communication of goals to staff (V104). Specific communication process is addressed elsewhere.

The questionnaire also checked whether fear was emphasised as a motivator:

(V071) Answer to what extent… [Fear was used as a motivator (e.g. loss of jobs or income).]

5.4.2 Goals, Regularity and Review—Incorporating PDCA

A concern from the contextualisation study was the lack of rigour applied to lean implementation. This was sometimes passed off as seeking a local solution without a proper structure or regularity. On-going PDCA is seen as crucial.

To extract aspects of regularity and focus the following questions were incorporated.

(V104) Rate the following. [Were staff given clear goals or performance indicators.]

(V078) Answer to what extent... [A program, structure or regularity for implementation was in place.]

The regularity of meetings and performance review was ascertained i.e.:

Give the closest answer:

(Daily, Weekly, Monthly, Quarterly, Bi-annually or Annually)

(V081) [Staff meetings were held]

(V082) [Performance review or support was provided to individuals

(V083) [Implementation review and planning was done by management]

Additional supporting questions included what extent the implementation had constant momentum i.e. did not stop and start (V032) as well as general communication and individual support questions. Experiment One also included a question on the need for regularity and focus in implementation (V059).

5.4.3 Journey View

Part of the vision for lean is that it is a journey. Leadership's view of a journey is beneficial to sustainability. Also, if all staff can have this attitude unnecessary resistance can be avoided.

The below question was included:

(V031) Answer to what extent the implementation... [was viewed as a journey, an ongoing process.]

Similar aspects are incorporated in other questions, for example maintaining change momentum (V032).

5.4.4 Fostering Behaviours or Generating Resistance

Leading change is related to leading people and their behaviour. Resistance to change might not be a sign of a negative employee character, but a lack of understanding, a lack of self-control or warranted resistance. People need to be treated appropriately in a change effort to address these reasons for resistance.

As well as many aspects of respect for people, resistance from staff was incorporated in experiment Two as the simple question:

(V102) Rate the following. [Did employees resist the change?]

And the previously listed management resistance was a comparator:

(V061) How much do you agree that management... [pressure is still needed for staff to maintain the lean behaviours.]

In addition, the questionnaire addressed aspects that support change: maintaining change momentum, engaging employees, aligning employee behaviours, developing staff understanding through communication, and staff trust of management.

A person's history can also affect their response to change. A question asked:

(V084) Did the staff have previous bad experiences that may have left a negative feeling towards change?

Additionally there is staff trust for management (V056), maintaining momentum (V070) and staff warned of the struggle (V076).

5.4.5 Guiding Coalition or Specific Promotion Function

The literature referred to Lean Promotion Functions. There are pros and cons of having a dedicated team for lean. Mainly the caution is that that all should be involved in lean and there should not be a feeling that an elite team of experts will do the job of improvement.

As well as asking about staff involvement, questionnaire Two referenced positive groups and having a guiding coalition:

(V077) Answer to what extent… [A guiding coalition or group of key staff were supporting the implementation.]

(V069) Answer to what extent… [Positive staff were grouped together (on purpose or by accident).]

The questions did not precisely include lean promotion function as a separate entity to a group of combined key staff.

5.4.6 Communication Process

Communicating the vision, staff roles, and other aspects of change in a simple effective manner to all staff is seen as essential. This is the sharing of the vision for a culture emergent approach (Figure 29, p. 136). Ideally, the communication breaks down large strategic goals and makes them applicable to each level of an organisation. Additionally communication processes were addressed.

(V050) How much do you agree that management...? [used an effective communication process]

(V088) How much where the following a feature of the implementation? [A3 Management, or Nemawashi or Catchball process]

5.4.7 Embed Culture First: Small Wins

Literature pointed to targeting small-wins, that is shrinking the change as opposed to generating a large crisis. These questions asked directly:

(V072) Answer to what extent… [Small wins (small events or improvements) were prominent in implementation.]

The point in using small wins ties together with embedding the culture rather than just using the most high impact methods. This view was assessed:

(V049) How much do you agree that management...? [viewed culture development more important than initial improvement gains]

An arguably opposing but popular concept is the use of improvement events:

(V090) How much where the following a feature of the implementation? [Kaizen (Kaikaku) Improvement Events]

This idea was also included in Experiment One:

(V067) Do you agree the following are crucial in the initial stage (year) of lean implementation? [Achieving large high impact improvement events to show the benefits.]

(V071) Do you agree the following are crucial in the initial stage (year) of lean implementation? [Achieve small but regular improvements.]

Experiment One also asked about management force (V073) and the use of simple techniques (V075).

5.4.8 Maintaining Change

Momentum, Cognitive Dissonance and Group Effects

Simply maintaining change is said to support the change, mere exposure to the change and new concepts develops cognitive dissonance. Also, utilising the group norm, the effect of the crowd is important.

The degree of momentum and the ease of maintaining momentum was asked directly.

(V032) Answer to what extent the implementation... [had constant momentum (did not stop and start)]

(V070) Answer to what extent… [It was easy to maintain momentum for change.]

The effects of groups were included to see if it impacted on the development of change. Literature mentioned these groups in context of being formed organically as well as specific functions. The question was left open:

(V069) Answer to what extent… [Positive staff were grouped together (on purpose or by accident).]

In this way maintaining change momentum, achieving cognitive dissonance and the support of group effects was incorporated

Identity with Growth Mindset Versus Defeatism

A new staff identity can be developed to support change. This concept recognises that how a person sees themselves effects how they behave. In an organisation of emergent change, the employees need to view themselves as those who can contribute to the company. This takes a change of mindset. Giving staff a new title can adjust their identity, which is how they see themselves and their role in the business. An example case of an *Inventors* program was given in the literature (Heath & Heath, 2010); as part of the industry contextualisation study, a similar identity program was trialled (p. 375).

An important aspect of this identity change is having a growth mindset, an acceptance of momentary failures en-route to the goal, otherwise defeatism can set in.

(V074)	Answer to what extent… [A new staff identity was developed (e.g. all staff are "Inventors" or "Improvement Engineers").]
(V075)	Answer to what extent... [Staff were helped to see that they could learn or improve with effort.]
(V076)	Answer to what extent… [Staff were warned of the struggle of change and the possibility of momentary failures.]

The journey view (V031) also contributes to a growth mindset. A question regarding staff identity was also included in experiment One (V070).

5.4.9 Supporting the Habits - Environment and Processes

The literature pointed to systems and processes to give cues to support new habits. Examples may be lines painted on the floor as part of a 5S initiative. These are like the rules that keep behaviours monitored that set boundaries. Visual systems lend themselves well to form habits by giving visual cues. Standard work with procedures and checklists also support new habits. However, these should be seen as a baseline measure that can be improved upon as opposed to being enforced by management.

This aspect was encapsulated in the questionnaire through visual systems and standard work. The questionnaire asked:

(V098)	How much where the following a feature of the implementation? [Visual Systems]
(V080)	Answer to what extent… [Procedures (standard work) were developed.]

Another question checked that improvements could be made:

(V048)	How much do you agree that management... [made it easy for staff to suggest and accomplish improvements]

Questions were asked on regularity, review, and positive group effects; these are also relevant to this section. Certain methods that support habits were also included in experiment One, like standard work (V095) and visual systems (V091).

5.4.10 Method Selection, Risk Analysis

In order to achieve the small wins and maintain momentum, the way methods are used is important. If a complex tool is used too soon, then the challenge of implementation may be too large, defeatism may set in.

The use of various methods was included in the questionnaire. There was also a reference to management understanding the methods, which is the basis for decision making:

(V067) Answer to what extent… [Management understood the tools and methods for improvement.]

Selecting methods for culture gain not just impact was included.

(V072) Answer to what extent... [Small wins (small events or improvements) were prominent in implementation.]

And as mentioned, an opposing concept to small wins is improvement events.

(V090) How much where the following a feature of the implementation? [Kaizen (Kaikaku) Improvement Events]

5.4.11 Situational Variables

In additional to all the mentioned factors for leadership and organisational development there are key situational variables. The situational variables are generally the demographics or descriptive statistics of the study. These are particularly important for a study of lean, because lean is seen as lacking contingency. These were incorporated into a key hypothesis:

Hypothesis 3: The key success factors for lean do not differ due to business size, and product mix.

Situational variables of particular interest were country (V005), industry (V023), organisation product type[83] (V025), business size (employee number V027), how long the implementation had been running (V028), and the organisations structure (how flat, V029). Additionally, the participants work experience (V007) and their role in the implementation (V019) was included.

5.4.12 Internal Resources

Resource availability is an issue, especially in the SME. This includes human resources, financial and physical resources; but also capacity and capability of key staff.

Questions asked regarding internal resources included financial and staff resource capabilities. The financial position was asked:

(V045) How was the company's finances (liquidity) during implementation?

This question was clarified by the help text:

> This refers to liquidity or cash flow condition. Please comment at the bottom of this page if you feel this had a particular effect on this implementation.

[83] Specifically variety and volume.

The influence of external support was also moderated.

(V043) Answer to what extent the implementation... [was initiated because of external support (e.g. government funded consultants or courses)]

Additionally internal capabilities in the form of personnel and technology resources were asked:

What is your estimation of the competence, capability, and calibre of the company's...

(V062) [Staff]

(V063) [Technology]

(V064) [Management]

(V066) [Implementation leader]

In this way, the capabilities of internal resources were included.

5.4.13 External Resources - Consultants, Teachers, Coaches, Sensei's

Consultants are commonly used to assist with lean in an organisation. This has been related to doing lean as a temporal project more than becoming lean. It is typical that a manager taking his hands off for a consultant to do process improvement by applying piecemeal lean tools. This gives the quick wins managers ask for but does not give lasting cultural change, and rather ends up as a passing fad and negative experience. However, that does not say there is no room for consultants and especially the coaching of a sensei in lean learning.

It is believed the best approach for implementation in SMEs is:

1. Commitment and a hands on approach from the manager.
2. A leading and coaching of the manager by a sensei style consultant.

In this way, the knowledge is retained with the manager in the organisation and the manager drives the change and continues so after the consultant is gone. The internal culture is developed as opposed to process improvement by an external expert.

The use of consultants was incorporated with three questions.[84]

(V035) Answer to what extent the implementation... [was conducted by consultants]

(V065) What is your estimation of the competence, capability, and calibre of the company's...? [Consultant]

(V073) Answer to what extent… [Consultants were used as a coach to train others (rather than doing themselves).]

[84] It was recognised that the consultant questions could have produced highly biased responses. An implementation that went well, for reasons other than the consultant, could have resulted in the consultant being praised.

These questions on consultants, in combination with the questions on key lean methods and the leadership factors address Hypothesis 2:

> ***Hypothesis 2: Consultants and the tools or methods of lean are secondary. The primary aspects are leadership and enabling development.***

5.4.14 Other Factors for Questionnaire

Additional factors are worthy of mention and were incorporated into the questionnaire. The impact of a positive start was included to see if it had significant effect on ongoing change:

(V033) Answer to what extent the implementation... [started well (good, steady and positive start)]

Matters of staff training were included:

(V054) How much do you agree that management...? [committed to training]

Supplier and customer interaction in the extended value stream were incorporated:

(V100) How much where the following a feature of the implementation? [Engaging suppliers]

(V101) How much where the following a feature of the implementation? [Engaging customers]

An existing culture, similar to the desired lean culture, could have impacted the success of lean. Hence the question:

(V103) Rate the following. [Did a culture similar or conducive to the desired culture already exist?]

And the inclusion of other factors “missed” by the questionnaire could be caught by text comments.

(V107) List other factors (if any) that you felt were important to the success and sustainability of the implementation. (e.g. relationship building with customers and suppliers, departmental or other factors)

As well as additional insights e.g.:

(V108) What would you do differently?

Further clarification was made possible through email contact:

(V111) Are you happy to be contacted regarding your answers to this survey? If so, leave your email address here. Your answers will no longer be anonymous to the researchers but will not be shared with other parties.

5.5 Outcomes of Conceptual Frameworks

To systematise the developed understanding of lean implementation a tentative framework was developed. This framework set groundwork for the questionnaire experiments. It integrated the outcomes of the literature review and contextualisation study(pp. 72, 130). In the framework many key factors are mentioned but practically no causal relationships are represented. The purpose of this model was to give a general overview of implementation. Causal relationships were hypothesised and tested as part of the structural equation modelling.

Lean implementation was presented as a planned change to take a business from an initial state to a lean business system of emergent change. Many success factors were compiled to support and measure implementation success. These factors were incorporated into questions for the survey. Additional situational variables were asked, as well as other miscellaneous factors and tools. Also the converse of certain factors was included, e.g. management empowering staff versus management enforcing change on staff. To ensure the tentative framework was adequately encapsulated the questions were tabulated against its components (p. 154).

See the appendix for the full questionnaire (p. 500).

5.5.1 Limitations

The number of questions was limited. It is possible some peripheral or only lightly referenced factors were not included in questionnaires. To counter this space for text comments was left in the questionnaires. Text comments provide opportunity for any other key factors to be identified by participants.

6. Correlation Experiment One—Lean Knowledge

Experiment One, the first of two questionnaire experiments, investigated lean knowledge and its influences. The purpose, was to investigate the differences in understanding, the different 'definitions' or constructs of lean and the correlations with lean knowledge. For this, the sample population embodies more than just avid lean practitioners but also those with low or no knowledge of lean.

Hypothesis 1 was:

> ***Hypothesis 1: The major success and failure factor for lean is leadership knowledge.***

Additionally this was opportunity to investigate the lack of lean knowledge in New Zealand managers addressing Hypothesis 4:

> ***Hypothesis 4: New Zealand's senior managers (represented largely by those in SMEs) have been slow to pick up lean management.***

6.1 Approach

Questions were formulated based on the conceptual constructs from literature review and contextualisation study as encapsulated in a conceptual framework (Tentative Framework, p. 134). Survey sections covered basic demographics, and a series of self-report questions that utilised Likert scales (ordinal text responses). Questions asked:

- Familiarity with lean (lean knowledge) and experience with implementation
- Specific understandings of lean
- Extent lean was considered a competitive advantage
- What was important in an implementation
- How important management knowledge was
- Various methods and their suitableness to the participants' organisation

Reviewing text responses showed less than 1% commented that the survey design was restricting. A full list of the questions and their abbreviations are in appendix on page 500. The survey format and ethics approval are also in the appendix (p. 495).

6.1.1 Distribution

Although the topic, Productivity Knowledge, did not seem relevant to many participants, Participants were encouraged to fill in the survey regardless of their own knowledge of the subject matter.

757 responses were gathered

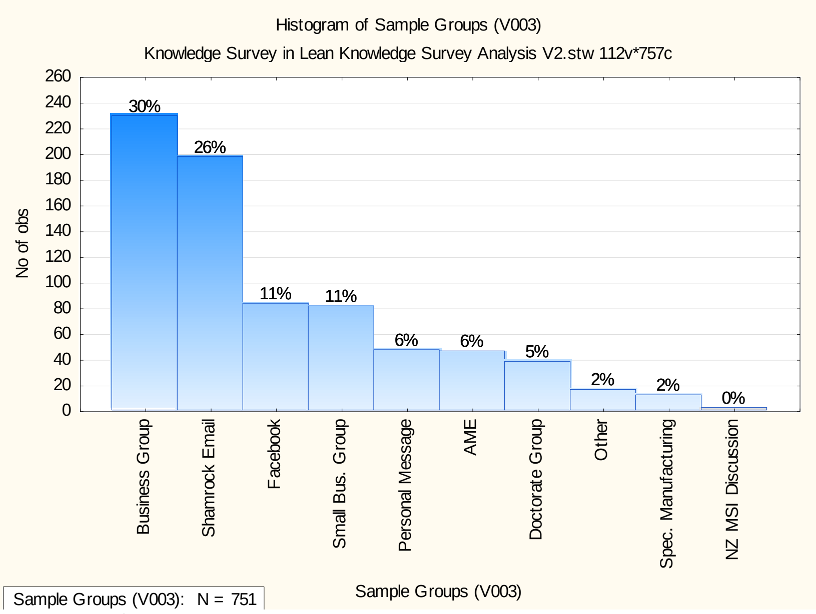
The response rate was difficult to calculate due to the various advertising mediums used. But personal communication was by far the most successful. Approximately 3430 personal communications were sent for this survey. A low estimate for the responses from personal communication is 600. That gives a very satisfactory 18 % return (Curtin, Presser, & Singer, 2000; Sheehan, 2001; Visser, Krosnick, Marquette, & Curtin, 1996).[85]

The majority of participants were from LinkedIn.com discussion groups. Members were contacted via discussion posts or direct group member message. These gathered 229 responses from Business Groups (30%) and from Small Business Groups 81 (11%), The Association for Manufacturing Excellence 46 (6%), Doctoral Students and Practitioners Group 38 (5%), and New Zealand Specialised Manufacturing 12 (2%).

Facebook provided 83 responses (11%). Three Facebook accounts were chosen. One male user 31yrs, New Zealand based, one female 32 years of age, New Zealand based with specific connections to the United States, and one female 50 + years of age based in the United States. This group represented a cross section of the general public better than the LinkedIn groups.

A local business (Shamrock Industries Ltd) made available their customers and suppliers details. Shamrock Industries are a local precision manufacturer and service provider. Resulting emails gathered 197 responses (26%) direct from industry.

Direct personal communication gave 47 responses (6%). Participant sample groups (methods of survey distribution) are shown in Figure 31.



Except for Shamrock Email, Facebook, Personal Message and Other, all categories are LinkedIn.com user groups. AME is the Association for Manufacturing Excellence,

Figure 31 Participant by sample groups Pareto chart.

[85] This response rate compares well with similar large-sample operations surveys (Ward & Zhou, 2006), e.g. 11% (T. A. Boyle, Scherrer-Rathje, & Stuart, 2011) and 7% (Ward & Zhou, 2006).

6.1.2 Bias

Certain sample groups were biased to specialist knowledge. Caution was required in interpreting and reporting descriptive findings. Case selection conditions (filters) were used to remove significantly biased groups where analysis was deemed vulnerable to skew e.g. identifying the distribution of lean knowledge in the population.

Consultants were over represented within the online discussion group sources. These consultants in general had a higher exposure to lean. Even with consultants removed, these groups still showed a higher familiarity with lean. These participants are believed more pursuant of knowledge, i.e. exhibited by participation in professional social networking.

Significantly biased towards lean knowledge was the Specialised Manufacturing and AME (Association for Manufacturing Excellence) groups (Figure 32). They did not represent the general manufacturing population let alone business population.

The Shamrock Email group was manufacturing bias as well as regional (to greater Christchurch, New Zealand where the majority of their business is conducted). See appendix, Analysis of Introduced Bias, p. 422.

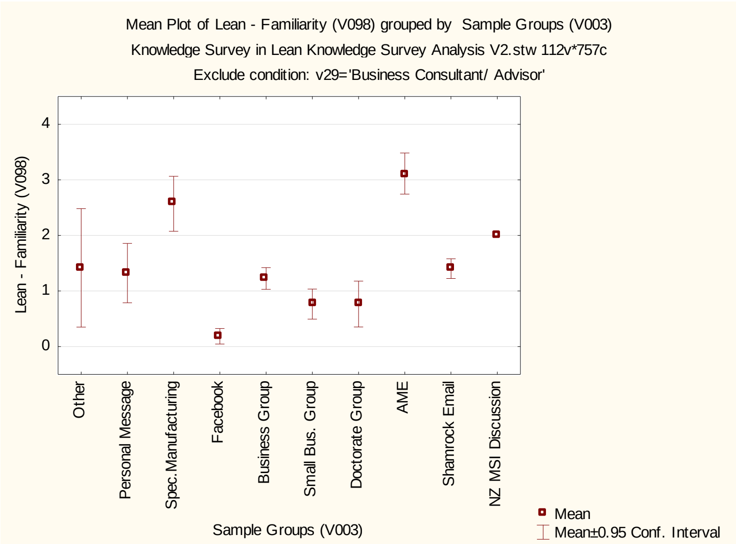


Figure 32 Lean familiarity means plots by sample groups showing within group bias. This chart excludes consultants/advisors.

6.1.3 Data Characteristics

The data set was sufficiently dense, with little missing values. The data did contain a natural drop out point for those who were not familiar with lean. Removal of cases was not needed as the data confirmed to these natural drop out points. There were not any specific insights from missing data. Advanced statistical methods (EFA and SEM) used case-wise deletion of data. Standard deviation of these Likert responses was reviewed by case, Figure 33. Only one case had Std. Dev. <0.7, i.e. 0.44. No cases were removed due to lack of variation.

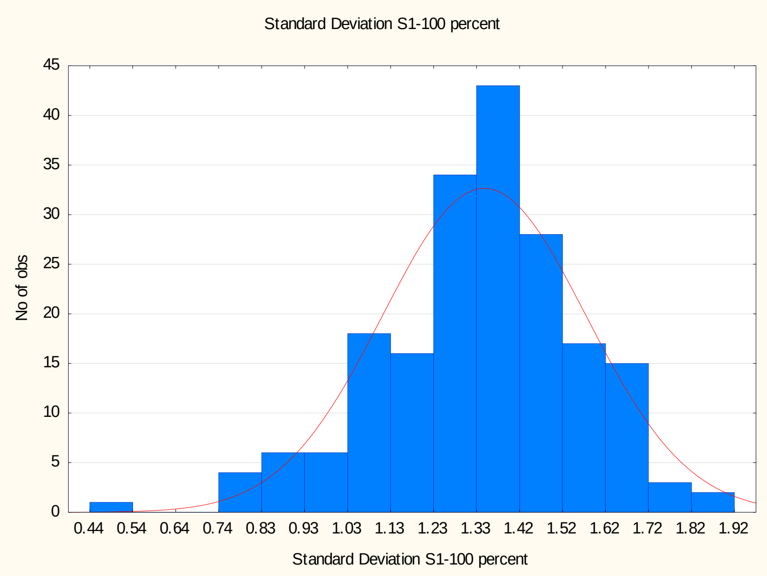


Figure 33 Standard deviation of responses to questionnaire One (case-wise deletion of missing data).

Initial screening of the data was by visual inspection of plots, typically histograms. Visual inspection was deemed more appropriate and pragmatic than statistical tests disconnected from reality (Hill & Lewicki, 2005). These plots are shown in the appendix (p. 428).

Statistical Assumption

A basic assumption across many of the statistical methods is linearity and normality. Most of the data came from textural ordinal variables arranged as 5 point Likert scales. Likert scales do not lend themselves to perfect normal distributions but the data was deemed acceptable for proposed methods. The data set was reasonably large so the *central limit theorem* supported the assumption. The methods chosen are fairly robust for deviations, e.g. ANOVA and PLS-SEM (see method p. 81).

6.2 Descriptive Statistics

6.2.1 Countries

The main countries represented were New Zealand (55%), Australia (16%), the United States (14%), and the United Kingdom (8%) as driven by the sample groups chosen. See Figure 34.

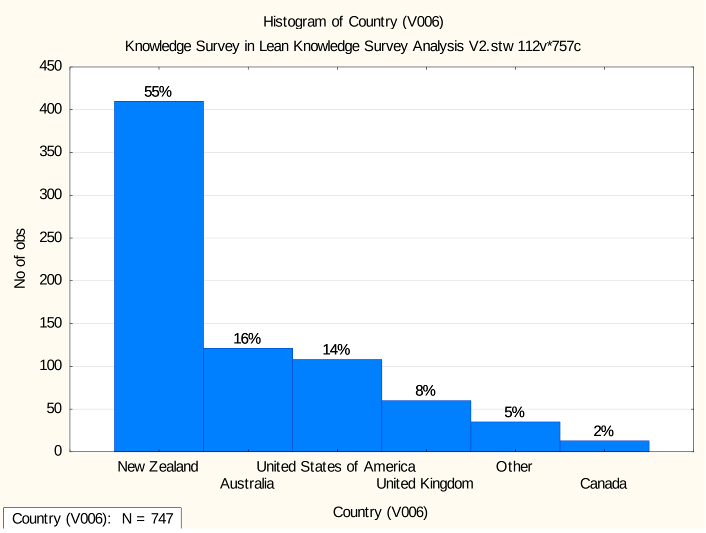


Figure 34 Country of residence Pareto.

6.2.2 Industries and Experience

The following plots Figure 35 and Figure 36 show participants by industry and work experience. Although industry is biased towards manufacturing (a main focus of this work), there is a large range of other engineering and service industries represented. Work experience is shows an appropriate distribution, although weighted towards intermediate and senior levels.

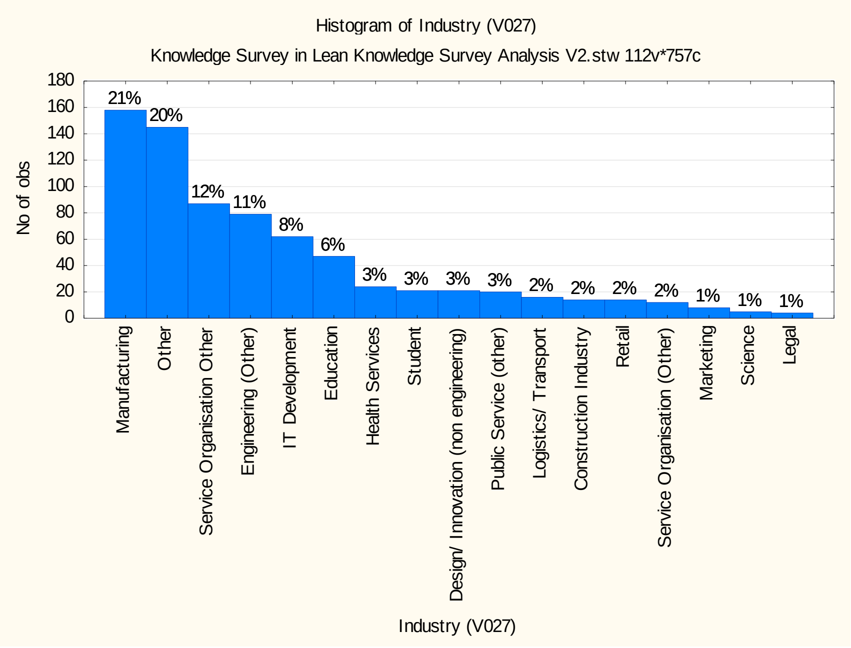


Figure 35 Industry Pareto chart. Participants were weighted towards manufacturing, engineering, and other related organisations.

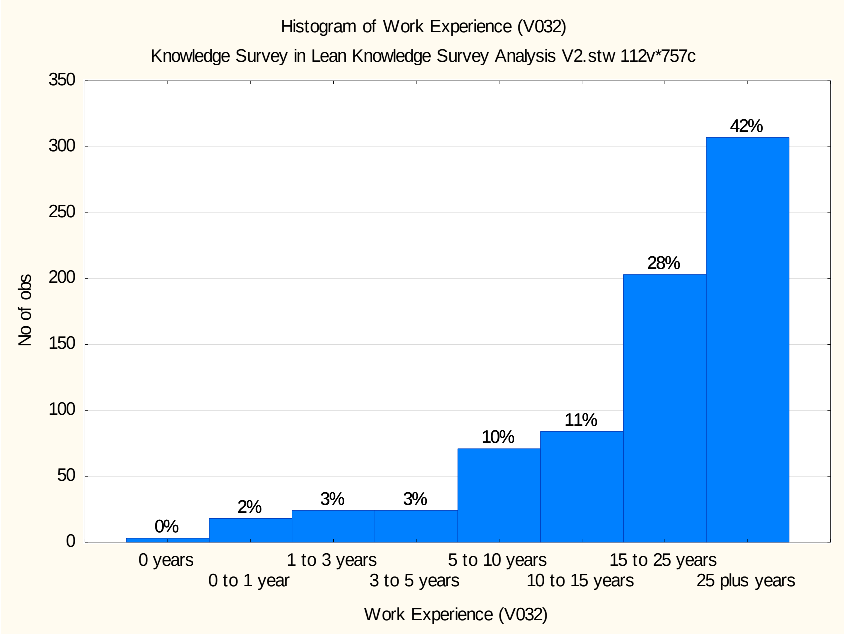


Figure 36 Participants by work experience level. The chart shows an appropriate distribution of experience although weighted towards intermediate and senior levels.

6.2.3 Highest Qualification

The majority of participants, 66%, had higher education (Bachelors or Postgraduate level). Future studies could gather lower qualification levels and industry positions also. Survey responses from lower levels of hierarchy were less likely, there is less interest in online networking and lower access to business email. This limitation was recognised at the outset of the study. There was little difference in response between the groups. See Figure 37 Highest education level of participants (Pareto chart. Also, see Figure 38 Highest qualification of participants by sample group (scatterplot).

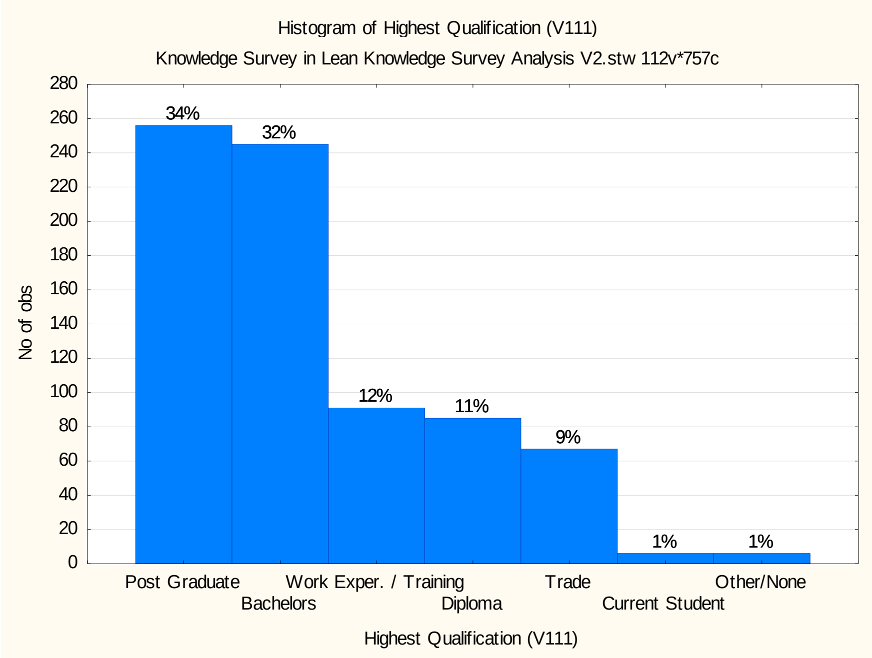


Figure 37 Highest education level of participants (Pareto chart).

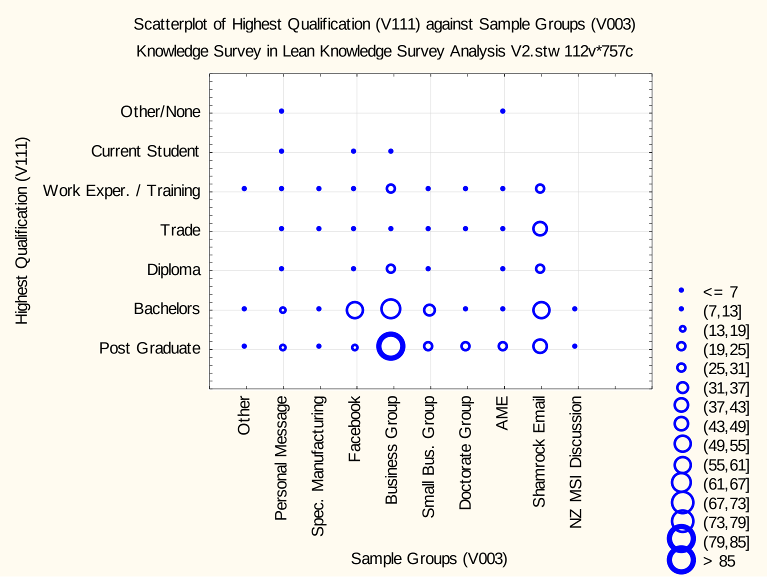


Figure 38 Highest qualification of participants by sample group (scatterplot)

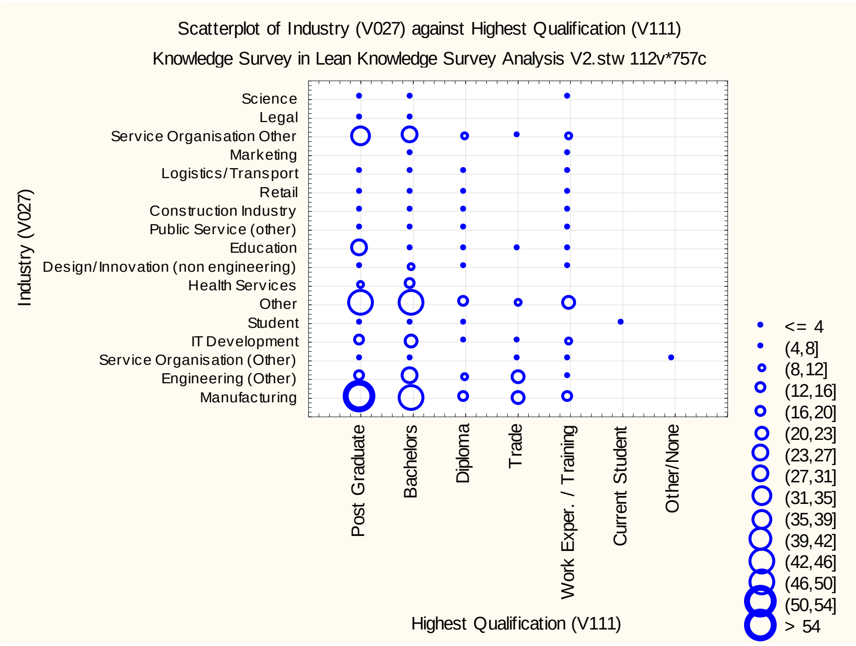


Figure 39 Highest qualification of participants by industry (scatterplot)

6.2.4 Knowledge Level

Full Population

Looking at the total population (with specialist manufacturing and consultant biasing removed) lean knowledge[86] was found non-existent in 55% (appendix Figure 208), this still showed bias.

[86] Participants' knowledge of lean was asked with the question: To what extent are you familiar with the following? Lean and/or the TPS (or variation of e.g. ACE, Lean Health etc.) - (V033)

Cross Sections of General Public and Manufacturing

The Facebook group proved to be a relatively unbiased representation of the general public. It achieved a good mix of adult respondents from various professional fields (Figure 41) and educations (Figure 42). Countries in this group were United States 46%, New Zealand 37%, United Kingdom 5%, and Australia 5%.

Familiarity with lean was *not at all in 88%, low in 9%, and high in 3%* (Figure 40). Lean knowledge is practically non-existent in the general public.

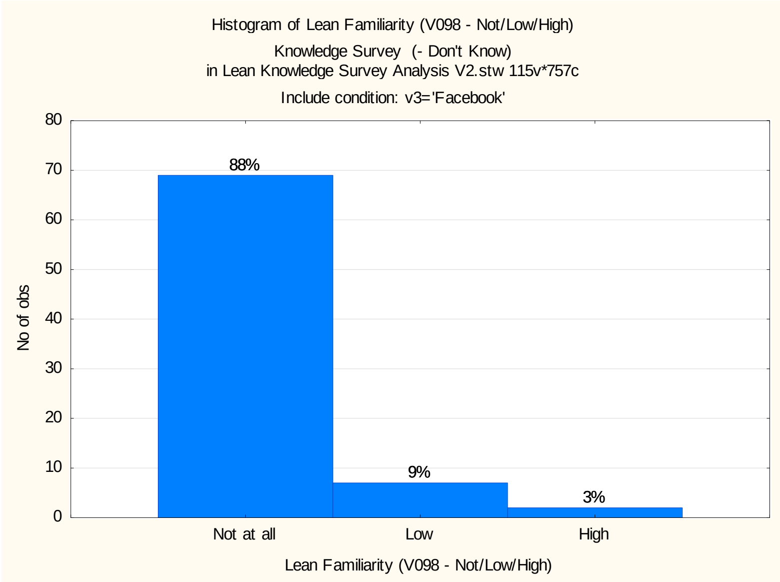


Figure 40 Lean Knowledge Level, General Population: Familiarity None, Low & High (general public – Facebook group).

Since lean was born in manufacturing, it is natural that many more participants from that field to have some familiarity with lean. However *one in six* (17%) (Figure 43) *of those in the manufacturing industry had no familiarity* (even though a positive bias was apparent). Knowledge of lean was observed low in 46% of manufacturing industry participants[87] and considered high in 38% of manufacturing industry participants.

Lean's knowledge saturation is still short in both the general public and manufacturing. The persons who don't know about lean and are not aware of its benefits would never apply lean.

[87] Percentages given here could have been moderated up and percentages for high knowledge level down to allow for known error in self-report (see Figure 208 on p. 13 and discussion section 0 on p. 38).

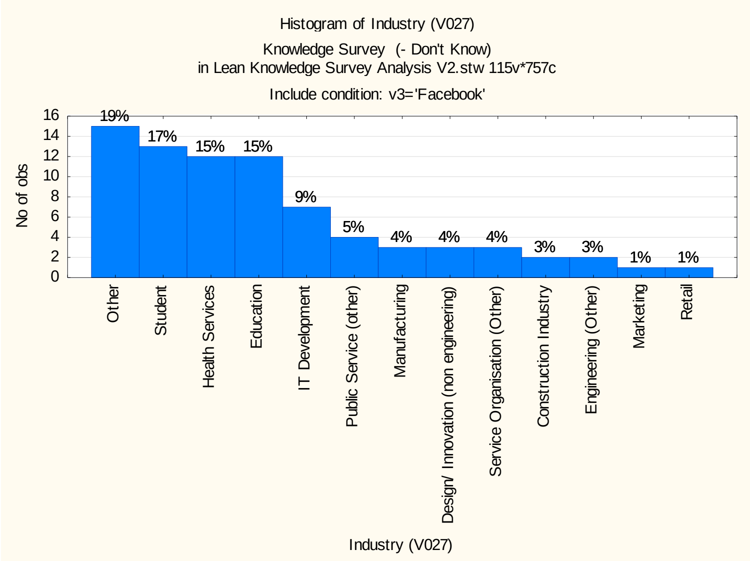


Figure 41 Industry represented (general public – Facebook group).

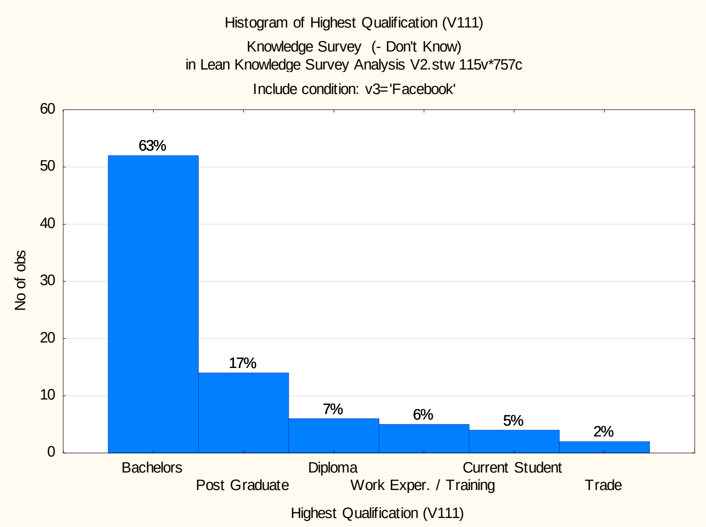


Figure 42 Highest Qualification (general public – Facebook group).

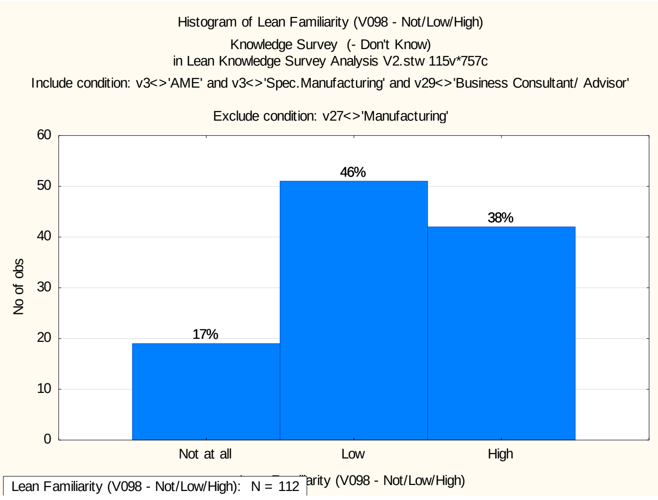


Figure 43 Lean knowledge level in manufacturing industry: familiarity none, low, and high (specialist groups and consultant biases removed).

Familiarity By Role - Manufacturing Sector

Box means plots of familiarity by role (Figure 215) show a larger range for familiarity in middle management and technical roles than senior management although the mean for senior management is higher. It is interesting that owner-operators typically had less familiarity with lean. This is in line with the interest in supporting smaller businesses that face further challenges finding themselves with less available resources and expertise. They may feel themselves self-sufficient (as indicated by text responses) but in doing so miss their true business performance potentials. The lack in performance of small businesses no doubt cripples the performance of New Zealand as a significantly SME based economy.

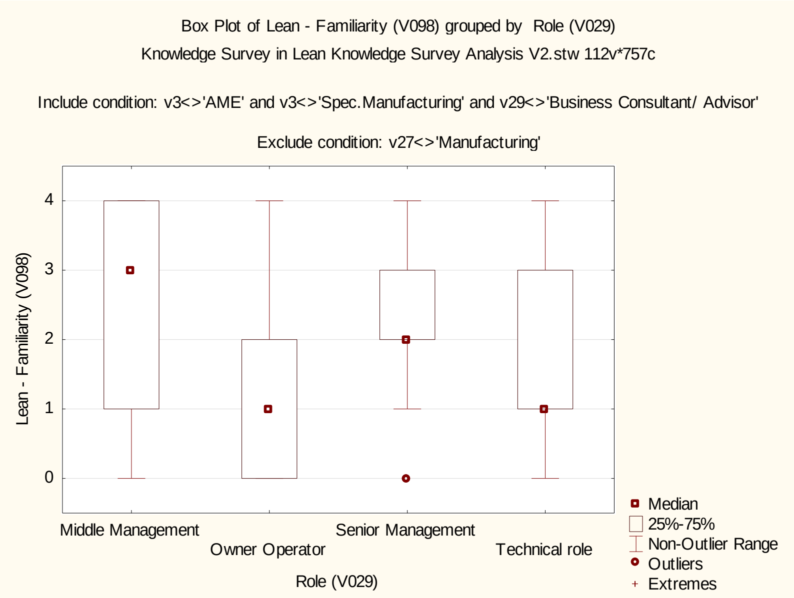


Figure 44 Familiarity with lean box plots by role –manufacturing sector, biased groups removed.

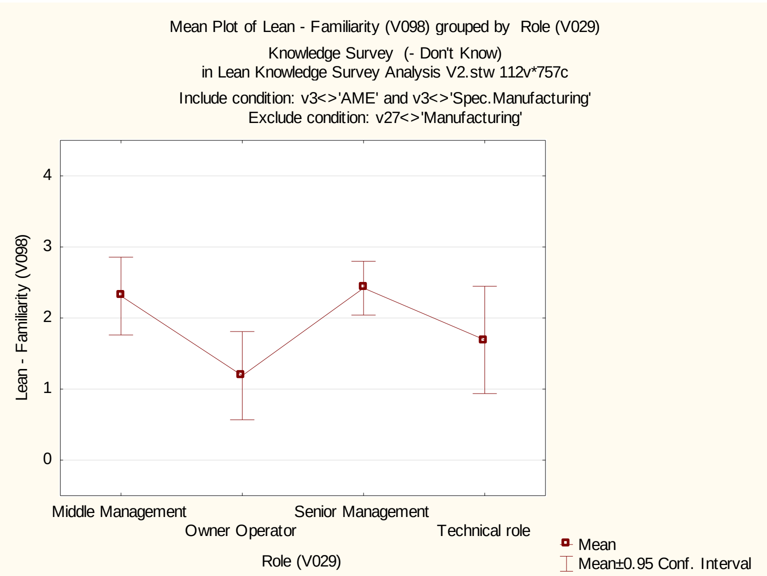


Figure 45 Familiarity with lean means plots by role –manufacturing sector, biased groups removed.

Comparing familiarity by role in manufacturing showed different data distributions. The distribution for senior management showed a relatively normal form, Figure 217. Owner operator familiarity showed skew towards no familiarity (43%, Figure 218), this was a concerning yet expected distribution, representing a focus on getting the job done as opposed to learning and development.

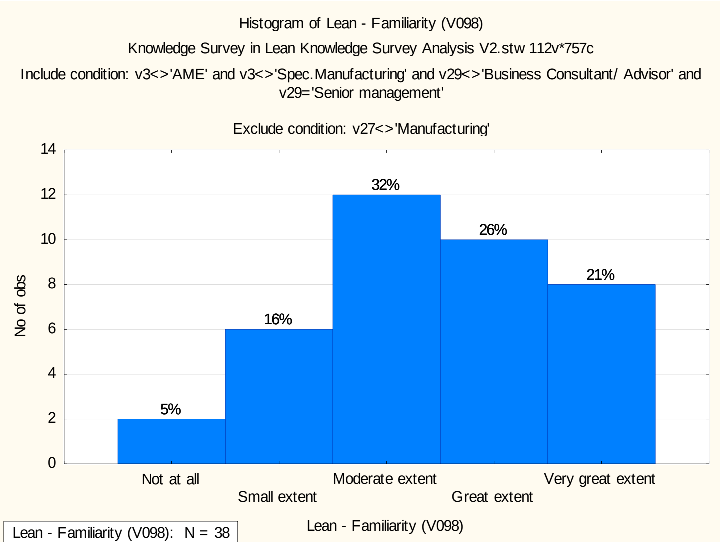


Figure 46 Familiarity with lean of senior management–manufacturing sector, biased groups removed.

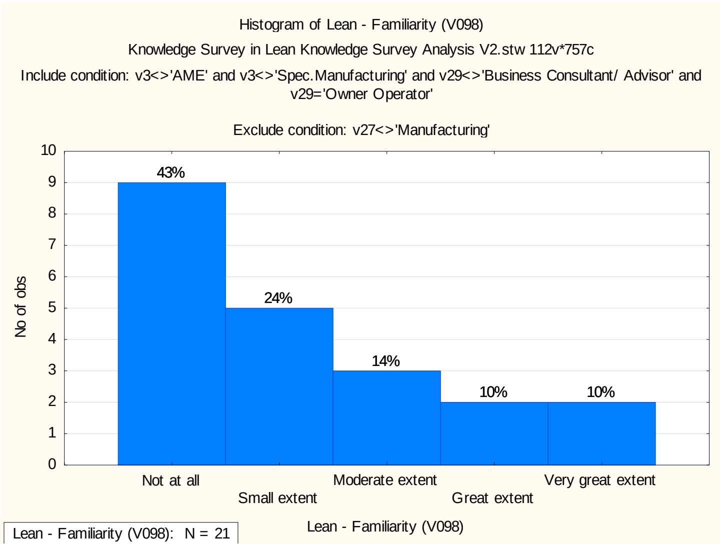


Figure 47 Familiarity with lean of owner operator –manufacturing sector, biased groups removed.

Middle management familiarity (Figure 219) showed a non-normal distribution, seemingly bi-modal, even though the sample size was similar to that for senior management[88] (n = 29 cf. n = 38). Similar non-normal distributions appeared for familiarity in technical roles (Figure 220), although response numbers were admittedly lower (n=13). It is believed the non-normal distributions reflects a dependency between the organisation's knowledge and leaderships' knowledge or pursuit of lean; the lower levels of hierarchy introduction to and familiarity with lean is highly dependent on leadership. If top leadership pushed heavily for lean, by default the staff would develop their own familiarity. If top leadership did not promote lean,

[88] In line with the *central limit theorem*, if data was normally distributed and the sample size was similar, it was reasonable to expect a similar, approximately normal distribution.

lower hierarchy staff would exhibit a low familiarity. Hence leadership knowledge and attitude becomes a moderating factor. This could tend towards a bi-modal distribution of essentially two distinguishable populations, one of employees whose leadership pursued lean and the other whose leadership did not. This links to the earlier framework for knowledge entrance into the business through management (Figure 26, page 127).

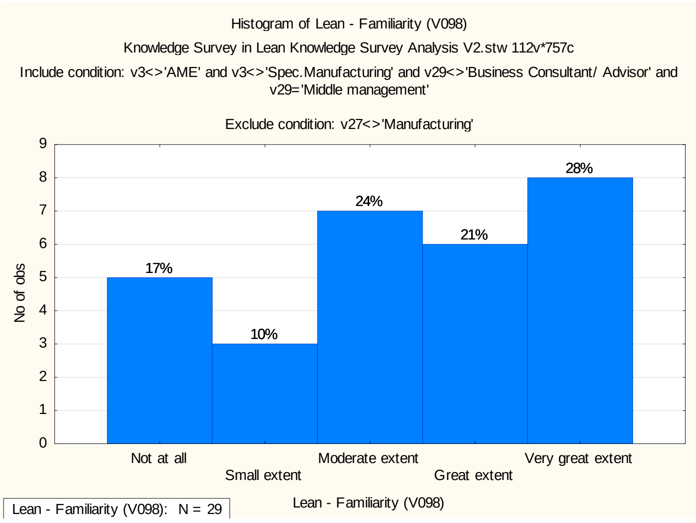


Figure 48 Familiarity with lean of middle management–manufacturing sector, biased groups removed.

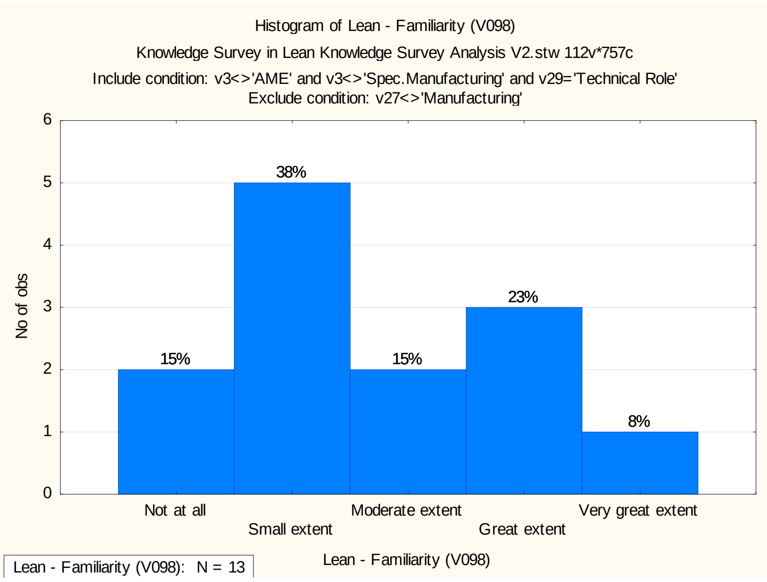


Figure 49 Familiarity with lean of technical role–manufacturing sector, biased groups removed.

6.2.5 New Zealand Comparison

Figure 50 Familiarity with lean – ANOVA means plot for manufacturing sector comparing New Zealand and the United States. A significant difference was found: p=0.00003, F(1,87)=19.2 (scale: 0=not at all, 4=very great extent).

Lean knowledge saturation was investigated by country.[89] Differences between the United States and New Zealand were observed for the manufacturing sector (Figure 50, also p. 397). The mean familiarity for United States scored 3.6 out of 4 whilst New Zealand scored only half that, 1.8. Further responses from the United States (ref. Figure 224) would be desirable. This would further increase confidence and reduce bias. Statistical results are still strongly significant, $F(1,87) = 19.2$, $p = 0.00003$. This indicates lethargy in New Zealand managers as expressed in Hypothesis 4:

> ***Hypothesis 4: New Zealand's senior managers (represented largely by those in SMEs) have been slow to pick up lean management.***

6.2.6 Self-Deception

It was shown that many participants were deceived about their knowledge of lean. Assessment showed actual knowledge levels were clearly below what was reported. Self-deception is evident where participants who reported to having great familiarity with lean actually had no knowledge of basic lean principles or methods (see figures, page 398). For example, 38% of those reporting great[90] familiarity said 5S was not relevant (5%) or not very relevant to their business (23%) or did not know of it at all (8%). It is very hard to believe that this basic principle does not apply and that someone with a high familiarity with lean would not know of it.

[89] The general population did not show any significant differences between countries.

[90] Self-reported "great extent"

Decision making is prone to error with self-deceived leaders. The implications of this to lean seem significant. One is not appreciating the benefits and not embarking on a lean implementation at all (failure). Another embarking on a substandard implementation that is prone to failure.

Although a leader may believe that a high level of understanding is crucial in implementing such change (as seen by responses, p. 386) they may be self-deceived into thinking they have the adequate knowledge. Implementation heads for an event of poor change management history (Bordia et al., 2011). *These bad experiences affect impressions of lean, seemingly confirming lean as another fad. The fad may be to embark on lean poorly, self-deceived, the practitioner thinking they know what lean is!*

6.2.7 Implementation Outcomes (Perceived Advantage)

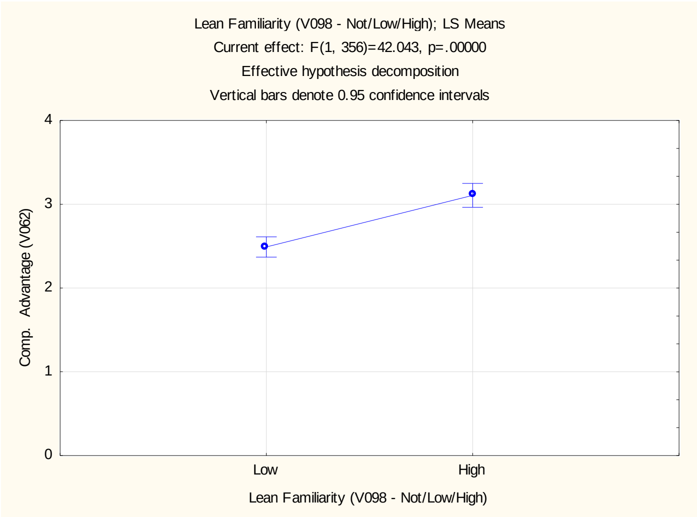


Figure 51 Competitive Advantage by Lean Familiarity (Low & High). Showing a significant ANOVA effect: F(1,356)=42.043, p< 0.00001 (scale: 0=not at all, 4=very great extent).

The different knowledge levels implied different outcomes of a lean implementation. In binary terms, there is success or failure. This is indicated by the strong relationship between familiarity and competitive advantage.[91] Effect of $F(1,356)=42.043$, $p< 0.00001$ observed between low and high familiarity. The perception of lean advantage (LS mean) transitions from a moderate level (2.5) at low lean familiarity, to great extent (>3) at high familiarity levels. Although both show some appreciation for lean, there is a great increase at high levels. Some participants commented that lean was not a competitive advantage but rather a necessity. This exhibits a VRIN[92] view of competitive advantage (Barney, 1991). This also implies the difference could have been stronger if an alternative question was used. For example, "to what extent does lean enhance business performance?" could have been asked.[93] This is a relative internal improvement rather than external comparison.

[91] The participants rating of the advantages of lean.

[92] Valuable, rare, inimitable, and non-substitutable

[93] For this reason this question was added to the implementation questionnaire.

6.2.8 Influences on Knowledge

Participants were asked why they had or hadn't pursued lean knowledge.[94] The analysis tallied 77 free text comments for why and 217 comments for why not. The highest occurring reasons are included[95,96] in Figure 52. The reasons why lean was pursued, the drivers for lean knowledge exhibited both active and more passive attitudes. Responses considered passive are indicated by (brackets and italics).

Lean Knowledge Factors

Why Pursued: Drivers		**Why Not Pursued: Inhibitors**	
For business performance	30%	I don't think it is relevant	34% (2)
(Employer introduced)	29% (1)	…even though I am not familiar with lean	16% (2)
Personal pursuit of excellence	18%	No time to learn	10%
(Known as required skill)	9%	I don't know how it can help	8%
For staff morale	6%	I am not required to	8%
(Learned in education)	6%	I get experts for this	2%
Want to empower others for continuous improvement	5%	I am doing something else	2%
		Costs too much	2%
Lean is essential	4%	Had bad feedback (Lean = Fad)	1%
For process improvement	4%	I learn as I need	1%
Lean is logical	3%		
(1) Responses considered passive indicated by *(brackets and italics)* These "passive" reasons are associated with external exposure.		(2) 46% of these responses were uninformed judgments i.e. those not at all familiar with lean (16%). 35% a small extent familiar and 20% moderately familiar.	

Figure 52 Lean Knowledge Factors: drivers and inhibitors for the pursuit of lean thinking (extracted from text responses)

The most proactive reasons were seeking business performance gains (30%) or personally pursuing excellence or improvement (18%). Others desired to empower staff, improve process, or just felt lean is logical and essential (~5% each). Less proactive pursuits were because of employer introduction (29%) and through other education (6%). Some pursued lean merely because it was a known skill for consulting or employment opportunities (9%). These later categories of employer introduction, other education, and required skill show less passion for improvement, excellence, or a "kaizen spirit" but are associated with external exposure. They are expected to correlate less with a sound knowledge of true lean. In some cases,

[94] Throughout the survey room was left for textural responses to allow freedom for expression of participant's opinion. Similar responses were coded and tallied for frequency. Full tables are included in the section 13.1.7 Textural Responses on page 143. A pragmatic approach was taken to coding, i.e. anything of repeated thought or particular relevance was tallied.

[95] Individual personal and psychological characteristics or traits would also play a part.

[96] Appendix has raw analysis table and so some factors were considered combined and some differences in nomenclature can be observed from Figure 52.

greater interest may be sparked through these introductions. The relationships between these categories and other variables could be investigated in future research.

The top reason given for not pursuing lean knowledge was “Lean is not relevant to my field” (34%). It is understandable that lean is simpler for and delivers results that are more significant in certain situations. It is hard to believe that lean is not relevant to the fields represented in this study (or any field). Lean is now commonly used in many areas beyond manufacturing and mass production including service industries, healthcare and education (lean universities) as well as lean government. Figure 53 shows the industries covered by “Lean is not relevant to my field” participants. Many of these participants were from engineering and manufacturing categories (30% combined).

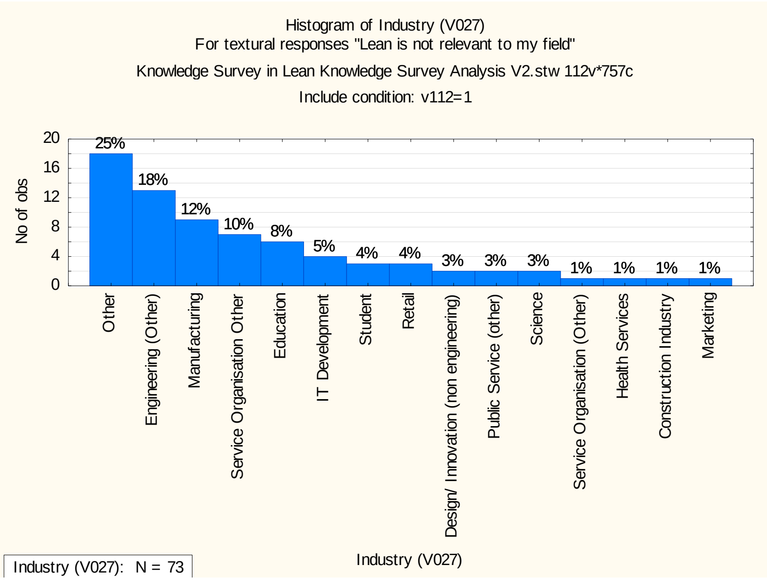


Figure 53 Industry Pareto for “Why haven't you pursued more lean knowledge?” = not relevant to my field.

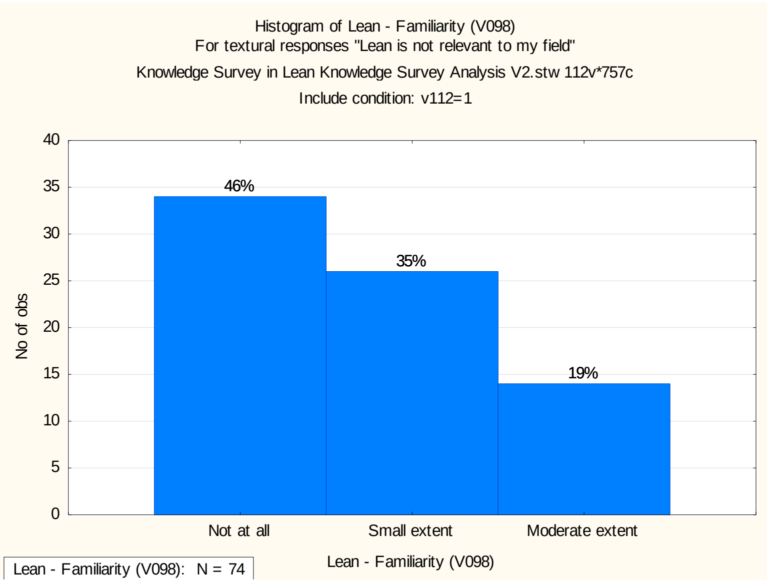


Figure 54 Histogram of familiarity for textural “Why haven't you pursued more lean knowledge?” = not relevant to my field. Showing 46%these responses was uninformed.

Forty-six percent of the participants who stated lean is not relevant to their field also reported they had no familiarity with lean (see Figure 54). Their response to relevance of lean had no basis according to their self-report. It is possible, they may have gleamed the tiniest amount of information on lean enabling a response, but not enough to assume a level of familiarity. The survey's title, *Knowledge Survey (Productivity Systems)*, and the questions asked, may have enticed the response "lean is not relevant". But it is believed many of these comments were made, without any knowledge and without hesitation, assuming they are knowledgeable in their field. Either way, this shows a significant barrier to lean uptake. If this exists amongst those with no familiarity with lean, similar unfounded resistance must exist at other levels of knowledge. This exhibits *self-deception* amongst participants.

Other responses included "I am not required by my employer" (8%) showing passivity. Many showed lack of understanding of lean and its application e.g. beyond manufacturing and mass production. And three had avoided lean because of others bad experiences. These are further indications of lack of knowledge, including misunderstandings that negatively impact lean success.

6.3 Different Understandings—The Lean Constructs

The principal analysis investigated different understandings of lean. The key questions for analysis were the "understanding" questions[97] as Figure 55.

Variable Name	**Do the following statements match your understanding of lean?**
Repacking of JIT/Qual. Sys (V050)	[Lean is simple repacking of JIT and quality systems, nothing new.]
Tools, processes (V051)	[Lean implementation is of tools and processes for improving productivity.]
Process Eng. (V052)	[Lean is tools or methods primarily for process or industrial engineers.]
Waste Elimin. (V053)	[Lean means eliminating waste.]
Train & Empower (V054)	[Lean gives workers training and empowerment to solve problems.]
Fragile/Unbuffered (V055)	[Lean means fragile (i.e. without buffers).]
New Systems/Ways (V056)	[Lean is implementation of new systems and ways of doing things to improve productivity.]
Respecting People (V057)	[Lean means respecting people.]
Philos./Strategy (V058)	[The implementation of a company wide philosophy and strategy.]
Needs regularity and focus (V059)	[Lean implementation process needs regularity and focus for sustained success.]
New label - Industrial Eng. (V060)	[Lean is a new label for industrial engineering and the work of industrial engineers.]

Figure 55 Experiment One key questions

[97] There were three main sections of questions. These were based around the understanding of lean, what was important in implementation, and the importance of leadership knowledge of lean. Additionally the applicability of lean methods was asked.

The main independent variable for the analysis was:

- Participants' familiarity with lean (as equating to level of lean knowledge)

Secondary comparisons were made by:

- Participants evaluation of leans competitive advantage
- The extent or experience had in lean implementation

Participant answered these on a 5 point scale of not at all, small extent, moderate extent, great extent, and very great extent. If they did not understand or did not know the answer, they could indicate this.

Preliminary investigation by linear models (ANOVA) found statistically significant differences ($P<0.05$) in 68% of the questions. 91% of the understanding variables and 33% of the implementation variables showed these differences; see Figure 200, p. 381.[98] This indicated significant differences in understanding exist and warranted further exploration.

6.4 Underlying Constructs—Exploratory Factor Analysis

Exploratory factor analysis (EFA) was used to uncover the underlying constructs and in effect reduce dimensionality (Fabrigar et al., 1999; Hill & Lewicki, 2005). Orthogonal approach was confirmed appropriate after trialling oblique rotations (Fabrigar et al., 1999), which uncovered no special insights (Figure 240, p. 411). There was an obvious secondary correlation[99] between a culture building implementation and the holistic view of lean uncovered.

Initially an r-matrix (correlation matrix) was produced and no variables were found correlating 'too high' i.e. $r > 0.8$ or $p<0.05$ (Field, 2013), i.e. no variables were removed before the iterative analysis.

Three iterations of EFA are presented here, initial (Figure 56), partial (Figure 57) and final (Figure 60).

The first EFA, 'iteration 0' was conducted over all understanding and implementation Likert questions. Four factors were extracted based on scree plot examination (Cattell, 1966; Field, 2013; Hill & Lewicki, 2005). Scree plot and unrotated matrix for iteration 0 are in the appendix (p.410), for an example see scree plot see Figure 58 below. Typically, factor loadings values > 0.3 are recognised as impactful but > 0.7 are desired for clear factors (Field, 2013). A sample size of 200 is recommended if looking at loading as low as 0.4 (Fabrigar et al., 1999). From the first iteration, the sample size was appropriate; 193 cases after case-wise deletion of missing data, as recommended (Field, 2013).

[98] Most of the significant differences were found across all three grouping variables: familiarity, experience and competitive advantage of lean. One was found by competitive advantage alone. See Figure 200, p. 57 for abbreviated and sorted table, or Figure 230, p. 68 for full ANOVA tables.

[99] Appendix Figure 240, p. 92.

	Factor (1)	Factor (2)	Factor (3)	Factor (4)
V062 Comp. Advantage	0.39	-0.14	**0.28**	0.31
V098 Lean Familiarity	0.76	-0.11	0.04	0.13
V106 Lean Impl.	0.82	-0.03	0.02	0.08
V050 Repacking of JIT/Qual. Sys	0.00	0.62	-0.08	0.00
V051 Tools or processes	-0.04	0.18	0.04	0.43
V052 Process Eng.	**-0.22**	0.68	-0.08	0.11
V053 Waste Elimin.	0.23	0.06	0.11	0.58
V054 Train and Empower	0.53	0.03	0.01	0.62
V055 Fragile/ Unbuffered	0.15	0.54	0.09	0.08
V056 New Systems/Ways	0.05	*0.17*	**0.16**	0.55
V057 Respecting People	0.52	0.05	-0.04	0.54
V058 Philos. / Strategy	0.40	0.02	0.00	0.52
V059 Needs regularity and focus	0.51	0.11	-0.02	0.32
V060 New label Indus. Eng.	0.00	0.76	0.02	0.04
V067 Large impact	0.20	**0.24**	0.10	0.00
V068 Best Methods	-0.14	0.11	0.55	0.10
V069 Comm. Process	0.07	-0.08	0.68	0.09
V070 Staff Identity	0.01	0.06	0.65	-0.04
V071 Small and regular	0.09	-0.12	0.47	0.15
V072 Key Staff Only	-0.09	0.33	-0.02	-0.11
V073 Mgmt Force	0.04	0.39	0.15	-0.02
V074 Technology	-0.36	0.32	*0.18*	0.07
V075 Simple Techniques	**0.21**	-0.04	0.31	0.10
V064 The extent that a manager understands Lean is critical for success.	0.00	-0.06	*0.19*	0.47
V065 In a small organisations management's understanding is top priority for success.	0.11	0.04	*0.18*	0.33
V116 Work Experience (~Likert)	0.04	-0.10	-0.08	0.12
Expl.Var	2.77	2.30	1.78	2.41
Prp.Totl	0.11	0.09	0.07	0.09

Factor Loadings (Varimax raw) Extraction: Principal axis factoring (Marked loadings are >0.3, **Bold** > 0.2, *Italics* ~0.2)

Figure 56 Factor loadings (rotated) for principal axis factoring iteration 0.

The rotated matrix shows key ‘factors’ that describe the differences in understanding; the underlying constructs that identify specific views of lean. Factor 1 identified with competitive advantage, familiarity, and implementation experience. It also correlated with lean as philosophy and strategy and respect for people, lean including training and empowerment for employees, lean including new systems and ways of doing things, and lean needing regularity and focus.[100] The second factor showed a tools view of lean as a repackaging of old methods. This factor had small (typically negligible) negative correlations with competitive advantage (-0.13), and familiarity (-0.1). It identifies a tools and process view of lean as a repacking of previous methods and exhibits a top down, management centric view of implementation. This factor (2) appears to be a confounding view of lean. Factor 3 and 4 showed negligible correlation with familiarity and implementation experience but stronger (~0.3) loading with competitive advantage. Apart from this factor 4 was near identical to 1, exhibiting minor variation. It did associate with management understanding variables V064 and V065 at lower levels loading (0.3 to 0.4). Factor 3 represents a view of

[100] ANOVA by comparison found very similar results.

lean implementation focused on culture development. This is seen as the seen as the culture building for Factor 1 and 4 although with somewhat orthogonal to them (possibly due to the other differences between 1 and 4). This approach to implementation includes careful selection of methods, a strong communication process, developing the staff identity, using small but regular activities (momentum), and focusing on the simple techniques.

Time in industry was expected to affect factor 2. A pseudo Likert variable[101] for years of work experience (V116) was included. Only a small relationship was observed with factor 4, it was subsequently removed.

Iteration of EFA for adequacy and construct validity achieved stronger factors. Adequacy with convergent validity is seen as loadings >0.7 are approached, specifically having all variables >0.4 is recommended for samples of ~200 (Fabrigar et al., 1999).

Iterations firstly removed weakly correlated (inadequate) variables. Additionally Factor 4 was deemed unnecessarily confounding. It had many shared relationships with Factor 1 and was weakly contingent on two lower loading (~0.3) variables. These variables were from near identical questions on management understanding (V064, V065). Thus, V064 and V065 were removed to simplify the structure. A three factor matrix resulted. The selection criterion was Kaiser's criterion of Eigen values >1 (Kaiser, 1960) and scree plot (Cattell, 1966) with logical elimination of factor 4, specifically removing variables V064, V065 (Hill & Lewicki, 2005). The resultant, partially iterated matrix is shown in Figure 57. It identifies all significant correlations; loadings >0.3 are shown in bold and weaker (non-discriminant) correlations in fine print. Correlations were ordered by factor and size. The three factors form the same constructs as previous; (1) a holistic view of lean, (2) a regurgitated tools and processes view with management centric implementation and (3) the culture building aspects of a holistic lean implementation.

This partially iterated matrix had non-discriminant (indiscriminate) variables loading multiple factors.[102] There was an obvious oblique, secondary relationship between the higher order view of lean with culture excellence including respect for people (factor 1) and a culture building implementation (factor 3).

A hierarchical analysis of oblique factors confirmed this (appendix Figure 240, p. 411). A 0.27 correlation was observed between factors 1 and 3. Negligible correlations were observed with factor 2 (-0.03 and 0.02).

Variables loading both factors 1 and 2 (non-discriminant) gave good insight to the different understandings or definitions of lean. V051 Tools or processes, V056 New Systems/Ways and V074 Technology were significant in both factors (being ~0.3 or >0.3). These were confounding by cross loading. These factors become implicated in the understanding of both higher and lower knowledge levels of lean. In this partially

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[101] This pseudo Likert was a 4 point ordinal scale but spacing increased over last increments (0 to 5, 5 to 10, 10 to 15, 15 to 25, >25). This variable was not seen to confound any results but should not be taken as conclusive that general experience in year, or similarly age wouldn't have shown effect if more adequately measured. The intention was to check the effect of time and the exposure to conjecture on developing methodologies.

[102] The non-discriminant matrix had loadings of approximately 0.3 or greater but was non-discriminant, many variables had 'significant' loadings to more than one factor.

iterated matrix, Lean Familiarity (V098) showed a -0.21 correlation in factor 2 but much stronger 0.65 in Factor 1.

	Factor (1)	Factor (2)	Factor (3)
V054 Train and Empower	0.80		
V057 Respecting People	0.75		
V098 Lean Familiarity	0.66	-0.22	
V106 Lean Impl.	0.66		
V058 Philos. / Strategy	0.65		
V059 Needs regularity and focus	0.61		
V053 Waste Elimin.	0.54		0.19
V062 Comp. Advantage	0.49		0.28
V056 New Systems/Ways	0.35	0.25	0.23
V052 Process Eng.		0.72	
V060 New label Indus. Eng.		0.71	
V050 Repacking of JIT/Qual. Sys		0.59	
V055 Fragile/ Unbuffered	*0.20*	*0.50*	
V074 Technology	-0.24	0.39	0.23
V073 Mgmt Force		0.35	
V072 Key Staff Only		0.30	
V051 Tools or processes	0.24	0.27	
V069 Comm. Process			0.69
V070 Staff Identity			0.61
V068 Best Methods			0.61
V071 Small and regular			0.46
V075 Simple Techniques	0.20		0.28
Expl.Var	3.77	2.31	1.78
Prp.Totl	0.17	0.10	0.08
	(1) Holistic Lean (2) Knowledge (3) Advantage	(1) Lean is Tools & a Repack of Methods (2) Top Down Change	Holistic (engaging) Implemntation

Factor Loadings (Varimax raw) Extraction: Principal axis factoring (Marked loadings are >0.3, Loadings <0.18 removed)

Reliablitity: Cronbach alpha Factor 1 = 0.8, Factor 2 = 0.7, Factor 3 = 0.7

Figure 57 Rotated factor loadings for principal axis factoring (partial iteration).

Confounding non-discriminant factors were iteratively removed to unveil a simpler structure. This was a process of adding and subtracting variables until an adequately discriminant matrix was formed. Ultimately four variables were removed; V062 Competitive Advantage, V051 Tools or processes, V053 Waste Elimination and V056 New Systems/Ways. Typically non-discriminant variables were removed if loading was higher than 0.2. Exception was for the case of V098 Lean familiarity where one factor, factor 1 loaded much higher than the other (0.7 cf. -0.2).

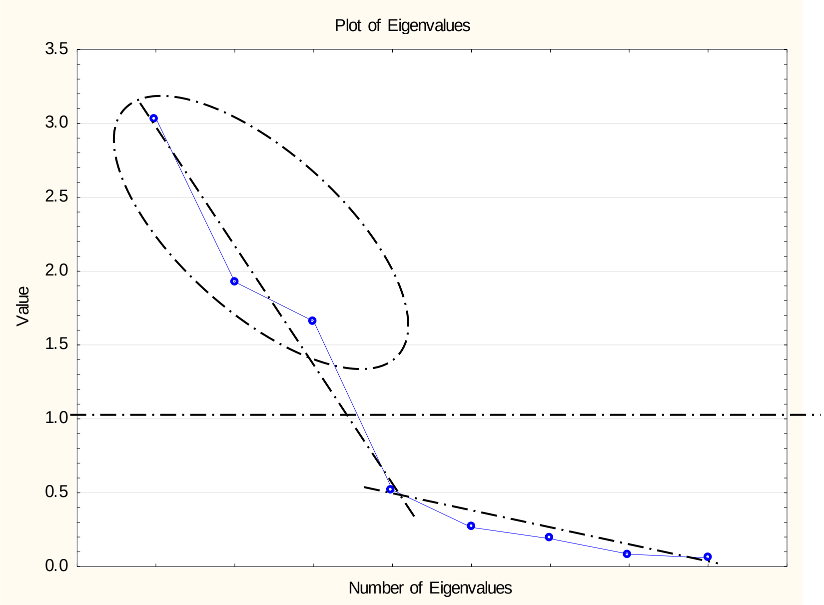

Figure 58 Scree plot for principal axis factoring final iteration, shows 3 clear factors with Eigenvalues > 1 and well after point of inflexion.

Value	Eigenvalue	% Total	Cumulative Eigen Value	Cumulative %
1	3.0	20.2	3.03	20.2
2	1.9	12.9	4.96	33.1
3	1.7	11.1	6.62	44.1

Figure 59 Eigen values and percent of variance explained, for principal axis factoring (final iteration).

The same factors came through in final iteration. The scree plot, Figure 58 shows three clear factors; i.e. Eigenvalues > 1 and positioned well after the point of inflexion. The unrotated matrix is in the appendix, Figure 241 (p. 412). The resultant rotated matrix, Figure 60 has all loadings >0.4 with minimum of 3 variables per factor. These factors describe 43% of the variance in the data with 20% being described by the factor 1 and 12% and 11% by the following (Figure 59). If four factors were extracted, they would have only covered 50% Figure 243, p.413. Ideally more variance would be explained by the final matrix, i.e. 50% or more (Field, 2013) but this is adequate for the work, unveiling the key underlying constructs as particularly represented by factor 1 and 2. This matrix was computed from 15 variables and 203 cases (after case-wise deletion).

	Factor (1)	Factor (2)	Factor (3)
V057 Respecting People	0.76		
V054 Train and Empower	0.75		
V106 Lean Impl.	0.66		
V098 Lean Familiarity	0.66	-0.18	
V058 Philos. / Strategy	0.65		
V059 Needs regularity and focus	0.63		
V060 New label Indus. Eng.		0.75	
V052 Process Eng.		0.70	
V050 Repacking of JIT/Qual. Sys		0.58	
V055 Fragile/ Unbuffered	0.19	0.57	
V069 Comm. Process			0.75
V070 Staff Identity			0.62
V068 Best Methods			0.59
V071 Small and regular			0.55
V075 Simple Techniques			0.42
Expl.Var	2.96	1.84	1.82
Prp.Totl	0.20	0.12	0.12
	(1) Holistic Lean (2) Knowledge	(1) Lean is Tools & a Repack of Methods (2) Top Down Change	Holistic (engaging) Implemntation

Factor Loadings (Varimax raw) Extraction: Principal axis factoring (Marked loadings are >0.3, Loadings <0.18 removed)

Figure 60 Rotated factor loadings for final iteration of principal axis factoring. Three factors extracted representing (1) Holistic Lean and Lean Knowledge, (2) Lean as Tools and the Repacking of Old Methods, and (3) Holistic (engaging) Implementation.

6.4.1 Principal Components Comparison

A principal components analysis (PCA) was used for cross comparison. This is arguably unnecessary but chosen for due diligence in methodology. Although principal components yield similar results to common factor analysis (and often are reported as such) they are different in principle. Common factor analysis (of which principal axis factoring is a type) are primarily for identifying the constructs or underlying data structure. Principal components is primarily for data reduction (Fabrigar et al., 1999; Hill & Lewicki, 2005; Lance & Vandenberg, 2009).

The same iterative process was taken for principal components as for principal axis factoring. Although PCA does not need rotation, they can be used to clean up outputs and aid interpretation (Dunteman, 1989; Field, 2013). Varimax rotations were applied here with little difference observed between unrotated and rotated. The same factors (more specifically components) were derived by PCA as PFA. Both the partial iterated and the final iterated matrixes are shown in appendix for comparison of PCA with PFA, see page 413. As PFA, an initial fourth component was dropped because it provided little insight and confounded the analysis.

Variables were removed for weakness to provide the partial iteration, (appendix Figure 244). This had identical variables to the PFA comparison, Figure 57. Confounding factors were removed to produce the final iteration, a discriminant matrix Figure 61. PCA final iteration (Figure 61) differs slightly to Figure 60 (PFA final iteration) because of small differences in loading in non-discriminant factors. These factors were faithfully removed according to the same rules as in PFA for fair comparison. Typically non-discriminant variables were removed if loading was higher than 0.2. Exception was V098 Lean familiarity where one factor (Factor 1) was loaded much higher than the other (0.7 cf. -0.2).

	Factor (1)	Factor (2)	Factor (3)
V054 Train and Empower	0.82		
V057 Respecting People	0.80		
V058 Philos. / Strategy	0.72		
V059 Needs regularity and focus	0.72		
V098 Lean Familiarity	0.69		-0.24
V106 Lean Impl.	0.67		
V053 Waste Elimin. (V053)	0.61		
V069 Comm. Process		0.81	
V068 Best Methods		0.75	
V070 Staff Identity		0.73	
V071 Small and regular		0.66	
V050 Repacking of JIT/Qual. Sys			0.68
V052 Process Eng.			0.81
V060 New label Indus. Eng.			0.82
V072 Key Staff only			0.40
Expl.Var	3.70	2.26	2.14
Prp.Totl	0.25	0.15	0.14
	(1)Holistic Lean (2) Knowledge	Holistic (engaging) Implemntation	(1) Lean is Tools & a Repack of Methods (2) Top Down Change

Factor Loadings (Varimax raw) Extraction: Principal Components (Marked loadings are >0.3, Loadings <0.18 removed)

Figure 61 Rotated factor loadings for PCA final iteration.

6.4.2 Factor and Component Analysis Outcome

The outcome of this factor analysis is the clarifying of underlying constructs and identifying their associated variables. This is represented in Figure 60 with Factor 1 being a holistic view of lean and lean knowledge; Factor 2 showing the view of lean as tools and processes, the repacking of old methods and a management centric or top-down view of implementation; and Factor 3 incorporating culture building aspects of a holistic lean implementation. The factors that were non-discriminant (indiscriminate) between Factor 1 and 2 were also identified as V051 Tools or processes and V056 New Systems/Ways.

The partial iteration, Figure 57 was particularly informative, showing significant non-discriminant variables as well as discriminant variables. The final iteration, Figure 60, shows the same constructs (factors) held through to an adequately discriminant solution. This was confirmed by PCA, Figure 61.

The relationships between the constructs were indicated but not adequately understood. *Structural equation modelling, incorporating the theory and EFA outcomes, was used to address construct relationships.*

6.5 Construct Relationships—Structural Equation Model

Structural equation modelling of (PLS-SEM[103]) was used to investigate relationships between lean knowledge and the perceived advantage of lean. EFA had identified the constructs but not specific relationships between them. Specific interest was in the mediation of advantages by the different understandings of lean:

> The holistic view of lean is believed to support the advantages of lean, achieving a learning organisation (C. Hendry, 1996; Hines et al., 2008).
> Knowledge is believed to indirectly affect the advantages perceived, developing the holistic view. This is in line with the knowledge-based view (Grant, 1996; Spender & Grant, 1996) and the proposal for deliberate learning (Zollo & Winter, 2002).
> The alternate view, of lean as merely tools and processes is believed unsatisfactory (Schmidt, 2011; J. P. Womack & Jones, 1996) not providing advantage but rather detrimental in the long term.

Latent constructs were established from the developed theory (p. 45) as supported by EFA (Figure 60). The resultant constructs are shown below:

Lean **Knowledge**	**Holistic Lean**
V098 Familiarity with lean V106 Experience with lean implementation	V054 Train and Empower V057 Respecting People V058 Philosophy/Strategy V053 Waste Elimination
Tools/Repack	**Perceived Advantage**
V052 Process Engineering V060 New Label for Industrial Eng. V050 Repacking of JIT/Quality Sys.	V062 Comp. Advantage

Figure 62 Construct indicators for SEM of lean understanding.

[103] See page 6 for explanation of PLS-SEM.

Lean knowledge is represented by participants' familiarity and experience, as seen in factor 1 (Figure 60). The construct Holistic Lean[104] included the remaining indicators of factor 1[105] (Figure 60). These all reference a holistic view of lean. *V059 Needs regularity and focus* could arguable remained but was removed; it represented the actual application more than the understanding. The Tools/Repack construct was extracted from Factor 2. The aspects of top-down implementation were removed to leave the understanding construct. Perceived Advantage was not a developed latent construct but was represented by one indicator. This is adequate for the purposes of this exploratory analysis.

A minimum of 30 samples is recommended for this model by rule of thumb (Joe F. Hair et al., 2011), i.e. 10 times the 3 paths acting on the endogenous latent variable. It would be unadvisable to limit to 30 samples but this provides comparison i.e. *the data set is substantial including 193 cases all 100% complete.* The significant data set tends to consistency at large.

6.5.1 Hypothesis Model

A hypothetical model (Figure 63) was developed to test the relationship between lean knowledge and perceived advantages. The developed model includes four latent variables:

Knowledge: the extent participants had knowledge of lean.

Holistic: the view of lean as a holistic business philosophy and strategy emphasising respect for people as well as methods.

Tools/Repack: the view of lean as tools and the repackaging of old methods.

Perceived Advantages: to what extent lean was considered a competitive advantage.

The model is explained by three hypotheses:

H1: The positive effect of lean *Knowledge* on the *Perceived Advantage* of lean is mediated by the Holistic view of lean.

H2: The view of lean as tools and repackaging of other methods, *Tools/Repack* has a negative relationship with *Perceived Advantage* of lean.

H3: The view of lean as tools and repackaging of other methods, *Tools/Repack* has a weak negative relationship with lean *Knowledge*.

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[104] In this work, to separate SEM constructs from the general text, they are denoted in title case, with capitalisation of the first letter of each word e.g. Lean Knowledge.

[105] As variables formed significantly different theoretical constructs the factor was separated between knowledge indicators and what was termed the holistic view of lean. The quality of the model and therefore this decision was confirmed. See Outer Model Quality, page 33.

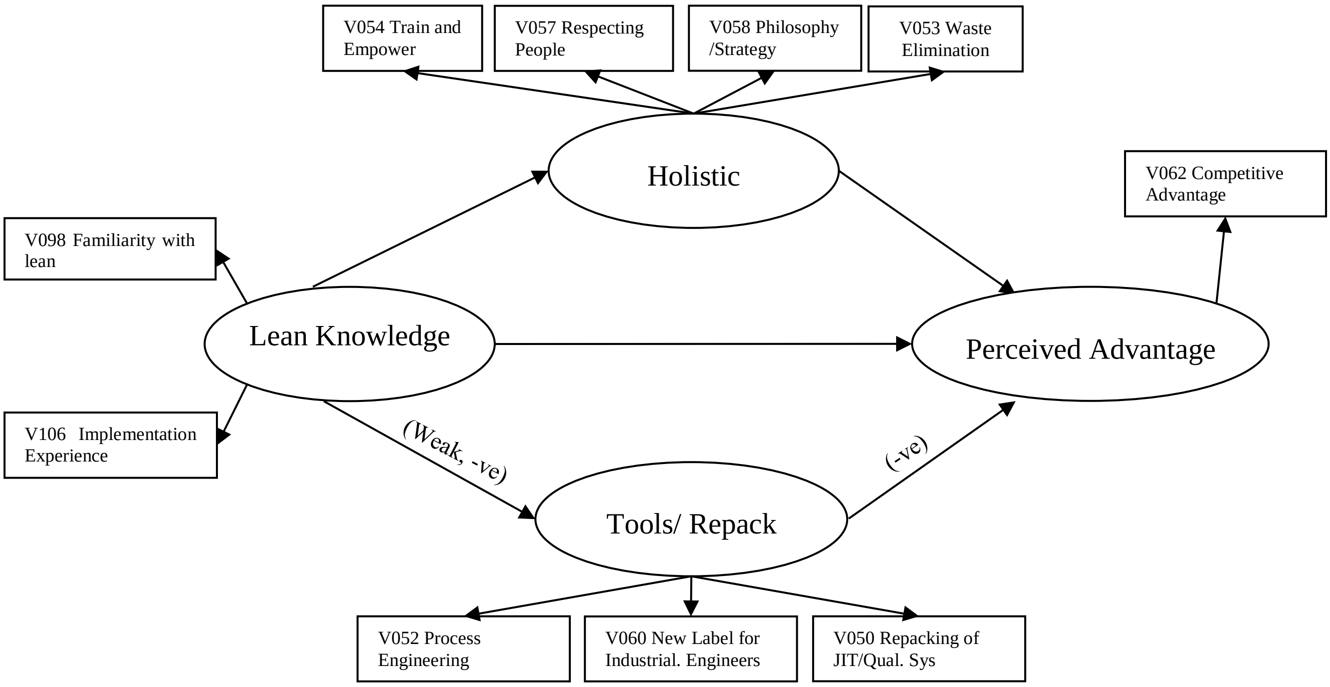

Figure 63 Hypothesis path model for the impact of lean knowledge on understanding and perceived advantage.

The models were run using the path weighting scheme (Joe F. Hair et al., 2012). Incomplete cases were removed for consistency with the EFA approach, 192 cases were included. Cross comparison with 90% complete data (Joseph F Hair, 2010) showed little difference.[106] Case-wise replacement of missing values (Parwoll & Wagner, 2012) was used in that comparison.

SEM outputs were tested to determine model quality. Specific assessment was for loadings in the outer (measurement) model, construct reliability, convergent validity, discriminant validity, inner model path coefficients (size and significance), and variance explained by target endogenous variables.

6.5.2 Validation of Model Quality

Statistical tests of model quality are below. The interpretable SEM path analysis model is on page 182.

Outer Model Quality

Loading of measurements on latent variables were all 0.64 or greater Figure 64. A basic standard for indicator validity is >0.7 although indicator loadings as low as 0.6[107] are considered acceptable in exploratory research like this (Joe F. Hair et al., 2011).

[106] The increased number of cases showed small changes in weak paths only and resulted in slightly weaker R^2 values. Mean replacement of data (reducing variance) showed slightly weaker results in paths. See appendix page 75.

[107] Even lower values are observed in newly developing scales and reliability is considered more important (Götz, Liehr-Gobbers, & Krafft, 2010). Lower loading indicators shouldn’t be removed carelessly. Reducing the number of indicators reduces consistency at large. Unless reliability is low (Henseler, Ringle, & Sinkovics, 2009) or there are high multicolinearity concerns (Götz et al., 2010) indicators should be retained.

	Holistic	Knowledge	Perceived Advantage	Tools/Repack
V050 Repacking Of JIT/Qual. Sys				0.79
V052 Process Engineering				0.82
V060 New Label For Industrial Eng.				0.72
V053 Waste Elimination	0.64			
V054 Train And Empower	0.82			
V057 Respecting People	0.64			
V058 Philosophy/Strategy	0.70			
V062 Competitive Advantage			1.09	
V098 Lean Familiarity		0.89		
V106 Lean Implementation		0.64		

Figure 64 Outer (measurement) model indicator loadings on constructs.

Traditional reliability assessment is Cronbach Alpha >0.7 (Nunnally, 1967). PLS is able to compute the more advanced composite reliability which allows for differences in factor loadings (Henseler et al., 2009). For exploratory research, composite reliability greater than 0.6-0.7 is recommended and greater than 0.7-0.9 is recommended for more advanced theory testing (Joe F. Hair et al., 2011). For convergent validity average variance explained AVE should be greater than 50% i.e. 0.5 (Fornell & Larcker, 1981). This means *"the latent variable is able to explain more than half of the variance of its indicators on average"* (Henseler et al., 2009, p. 299). See others also (Götz, Liehr-Gobbers, & Krafft, 2010; Joseph F Hair, 2010). These criterion are comfortably met for the model in discussion, see Figure 65.

Discriminant validity implies significant differences between the different constructs, i.e. the constructs are discriminant (Henseler et al., 2009). Fornell–Larcker criterion (Fornell & Larcker, 1981) has been called the best method for assessing of discriminant validity (Farrell & Rudd, 2009; Farrell, 2010). Fornell–Larcker criterion is commonly represented as the square root of the AVE for a latent variable being greater than any loadings between it and the other latent variables (Farrell, 2010; Henseler et al., 2009). Confirmation of discriminant validity by this criterion is seen Figure 66. An alternative check is that the indicator loads on its construct higher than on all other constructs (Joe F. Hair et al., 2011; Henseler et al., 2009) as seen in Figure 67.

	AVE	Composite Reliability	Cronbach Alpha
Significance criteria	*>0.5*	*>0.6*	*>0.7*
Holistic	0.64	0.88	0.81
Knowledge	0.87	0.93	0.85
Perceived Advantage	1.00	1.00	1.00
Tools/Repack	0.62	0.83	0.72

Figure 65 AVE and reliability for SEM of lean knowledge.

	Holistic	Knowledge	Perceived Advantage	Tools/Repack
Holistic	**0.80**			
Knowledge	0.49	**0.93**		
Perceived Advantage	0.43	0.41	**1.00**	
Tools/Repack	0.00	-0.17	-0.15	**0.79**

Fornell–Larcker criterion, √ (AVE) >factor loading, Bold = √(AVE), plain text = factor loadings.

Figure 66 Discriminant validity by Fornell–Larcker Criterion (Fornell & Larcker, 1981) for SEM of lean knowledge.

	Holistic	Knowledge	Perceived Advantage	Tools/Repack
V050 Repacking of JIT/Qual. Sys	-0.01	-0.04	-0.18	0.72
V052 Process Eng.	-0.02	-0.22	-0.11	0.89
V053 Waste Elimination	0.68	0.29	0.24	0.05
V054 Train and Empower	0.90	0.47	0.44	-0.03
V057 Respecting People	0.85	0.45	0.34	-0.01
V058 Philosophy ./Strategy	0.77	0.33	0.34	0.00
V060 New label Industrial Eng.	0.05	-0.08	-0.04	0.75
V062 Competitive Advantage	0.43	0.41	1.00	-0.15
V098 Lean Familiarity	0.46	0.94	0.39	-0.19
V106 Lean Implementation	0.46	0.93	0.37	-0.12

Figure 67 Cross loading matrix for review of discriminant validity.

Significance of paths was tested by bootstrapping to 5,000 iterations (Joe F. Hair et al., 2011), although 500 iterations (Camison & Villar-López, 2012) converged to near identical solution. Various sign change options were trialled. Ultimately the individual sign changes option was used where *"signs in the outer and inner models of each resample are made consistent with the signs in the original sample in order to avoid these sign-change related problems"* (Henseler et al., 2009). This diminishes the risk of reduced t-value due to an arbitrary sign change during bootstrapping analysis, and is recommended (Henseler et al., 2009). Significance levels or criteria by t-values are 1.65 for 10% (α=0.1), 1.96 for 5% (α =0.05), 2.58 for 1% (α =0.01) for sufficiently large samples.[108] All *measurement model* paths showed high significance in bootstrapping, Figure 68. The indicator paths Tools/Repack were the weakest in the outer model but still highly significant t-value's from 4.3 to 5.8, much greater than 2.58 or α =0.01.

Inner Model Quality

Inner model paths between latent variables for Knowledge->Holistic->Perceived Advantage and Knowledge->Perceived Advantage were strongly significant, p>0.01 (bootstrapped). The significance level of Knowledge->Tool/Repack was exactly p=0.01. Allowing for individual sign changes gave the highest

[108]A large sample is typically taken as greater than 30 degrees of freedom. Degrees of freedom can be conservatively calculated as n-2.

significance value for Tool/Repack->Perceived Advantage, t=1.5 (t-value was 1.2 for no sign changes and construct level changes alternatives). This still did not meet lowest α significance level, 0.1.

The variance explained, R^2, needs to be sufficient. R^2 results are typically categorised as substantial, moderate, and weak. One scale is 0.67, 0.33, and 0.19 (Chin, 1998b; Henseler et al., 2009) and a similar alternative 0.75, 0.50, or 0.25 (market research Joe F. Hair et al., 2011). Moderate values are deemed acceptable if only a few latent variables are exogenous. If several latent variables are acting, substantial values are suggested (Henseler et al., 2009). This criterion is dependent on context, e.g. in consumer behaviour 0.2 is considered high (Joe F. Hair et al., 2011). That said, a minimum of 0.1 is a reasonable guideline (Camison & Villar-López, 2012; ref. Falk & Miller, 1992).

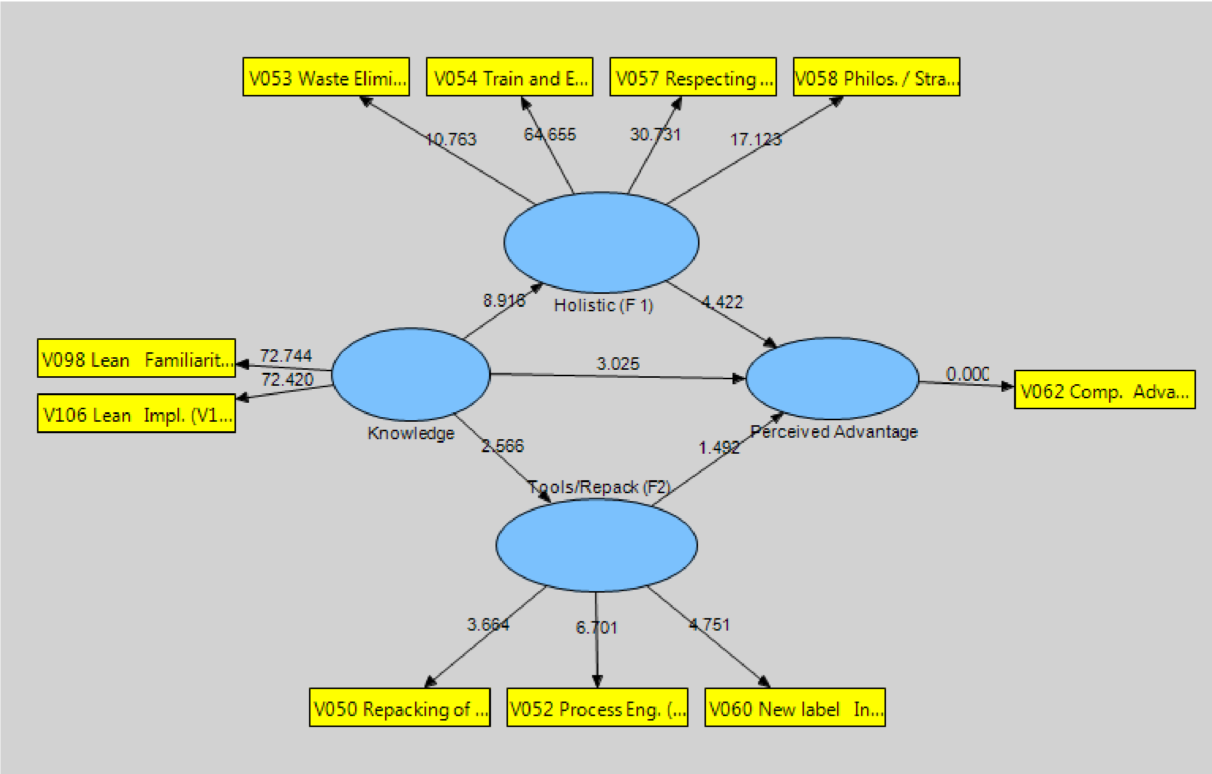

Figure 68 The impact of lean knowledge on its understanding and perceived advantage: boot strapped path model showing T-statistic (5000 iterations, 193 cases 100% complete, individual sign changes allowed). Significant t-values are 1.65 for 10% (p=0.1), 1.96 for 5% (p=0.05), 2.58 for 1% (p=0.01).

	R^2	Communality
Holistic	0.24	0.64
Knowledge		0.87
Perceived Advantage	0.25	N/A (Single Item)
Tools/Repack	0.03	0.62
Average	0.17	0.71

$$Gof = \sqrt{Ave.Communality \times Ave.R^2}$$
$$where\ Gof > 0.31\ is\ acceptable$$

Gof = 0.35

Figure 69 R^2, communality, and Goodness of Fit for the impact of lean knowledge on its understanding and perceived advantage.

The model here is exploratory, has early stage constructs, and one variable acting endogenously. The , R^2 values of 0.24 for Holistic and 0.25 for Perceived Advantage could be taken as moderate if not substantial (i.e. 0.2 = high in consumer behaviour Joe F. Hair et al., 2012). Tools/Repack however was very weak at 0.03, i.e. <0.1(Camison & Villar-López, 2012). See Figure 69.

A goodness of fit[109] (GoF) of 0.35 was achieved for the model. The minimum GoF recommended is 0.31 (Camison & Villar-López, 2012; Tenenhaus, Vinzi, Chatelin, & Lauro, 2005). But strictly, GoF needs to be interpreted with the support of other tests (Henseler & Sarstedt, 2013). Ultimately, the effects through Tools/Repack were small but beneficial to be left in the model for discussion.

6.5.3 Resultant Structural Model

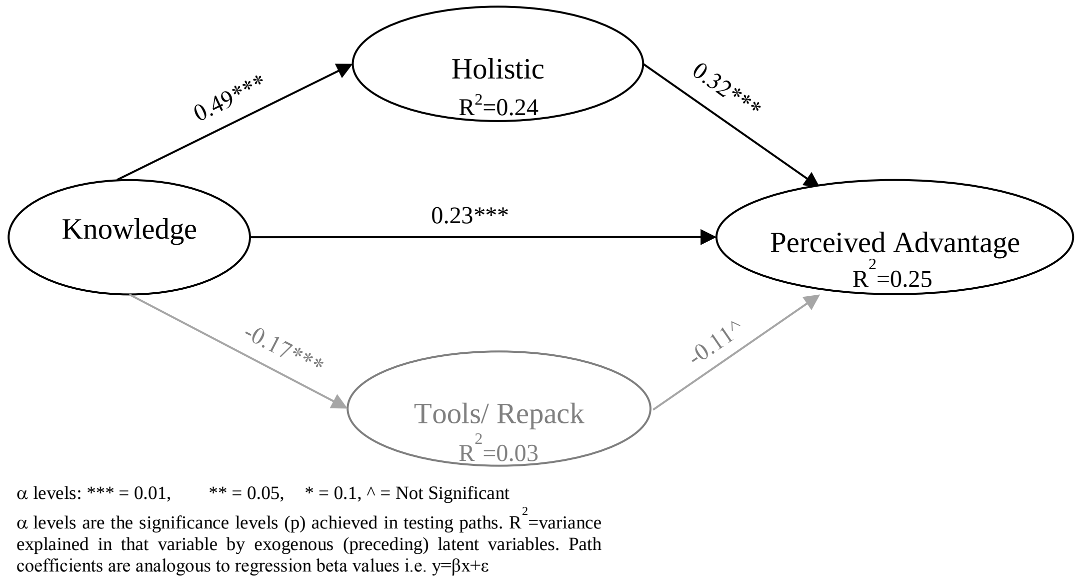

Figure 70 Structural model for the impact of lean knowledge on understanding and advantage. R^2 is variance explained by incoming paths.

[109] GOF focuses on the difference between predicted values and those observed, for measures or approximated, for latent variables. This is different from model fit in covariance based SEM which compares the theoretical covariance matrix with the empirical one (Henseler & Sarstedt, 2013).

The resultant structural model is shown in Figure 70. SEM path coefficients are analogous to beta (β) values in a standard regression equation, $y=\beta x+\varepsilon$. The path Knowledge->Perceived Advantage has $\beta=0.23$. Stronger β are observed by the moderating effect. Knowledge-> Holistic, $\beta=0.49$ and Holistic-> Perceived Advantage, $\beta=0.32$.[110] All are significant to $\alpha = 0.01$. This supports H1.

Accept H1 The positive effect of lean *Knowledge* on the *Perceived Advantage* of lean is mediated by the Holistic view of lean

A small negative relationship $\beta=-0.11$ was observed between Tools/Repack and Perceived Advantage of lean. This relationship was insignificant. The constructs are not fully developed but the data set is reasonably large and all other paths converged to high α of 0.01. Lack of consistency at large is not likely to be a factor and if so, the relationship (β value) would still be weak. Therefore, H2 is rejected.

Reject H2 The view of lean as tools and repackaging of other methods, *Tools/Repack* has a negative relationship with *Perceived Advantage* of lean.

No relationship was found between the Tools/Repack view of lean and perceived advantage, i.e. negative or positive.

A negative relationship $\beta=-0.17$ was observed between the Tools/Repack view and Knowledge. Although weak the relationship was significant to α of 0.01 exactly (t-value=2.6).

Accept H3 The view of lean as tools and repackaging of other methods, *Tools/Repack* has a weak negative relationship with lean *Knowledge*.

The weakness of this relationship was highlighted by a small R^2 (0.03). Although goodness of fit for the model was acceptable, only 3% of the variance of Tools/Repack was explained by lean Knowledge. For this reason, Tools/Repack has been displayed grey in the model, Figure 70. The exogenous factors influencing the Tools/Repack construct are unknown and need further investigation.[111]

The holistic understanding of lean correlates with lean being a competitive advantage and develops with knowledge, i.e. mediating between knowledge and perceived advantage. The view of lean as tools and repackaging of other methods did not correlate to perceived advantage. Its relationship with knowledge (although statistically significant) was negative and weak describing insignificant variance.

These results can be extrapolated to the outcomes of implementation contextually. The way lean is understood has significant effect on the outcomes as represented by the advantages perceived.

[110] Relationship to advantage outcome would have been stronger given different terminology or additional scale items, e.g. some considered lean essential so not a competitive advantage but having it is definitely a benefit to business.

[111] A trial was conducted using a work experience categorical as a pseudo 5 point Likert scale, this showed no significant relationship. This was to investigate both work experience and by inference age. Further investigation is required.

6.6 Knowledge Framework

Understanding lean differently produces different results. The novelty here was to (1) empirically define what the differences were and (2) to what extent increasing lean knowledge describes the variance. To represent the insights and statistical data a framework with graphical model was developed. The initial investigation had developed tentative models of lean knowledge (e.g. p. 129), but a further model was needed to represent the additional insights of the survey.

6.6.1 Contextual Development

It is logical that the level of lean knowledge and particularly leadership knowledge effects implementation outcomes. Implying, the higher the level of knowledge the greater the chances of success. The more knowledge possessed regarding a thing the more wisdom or skill and ability can be applied in handling that thing. This concept is not particularly novel in itself. For this reason, it has been labelled the logical construct. When knowledge increases, the understanding increases in various facets and enables better application. The logical construct of lean knowledge and its effect on lean success is presented in Figure 71.

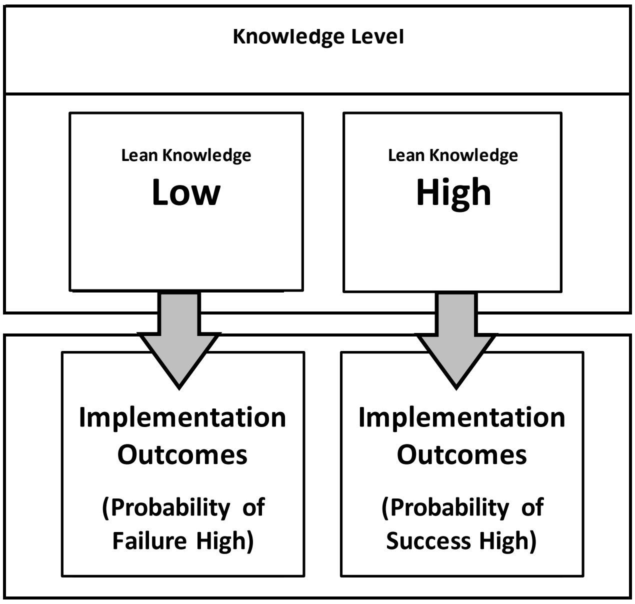

Figure 71 Logical model: the logical construct of lean knowledge for lean success.

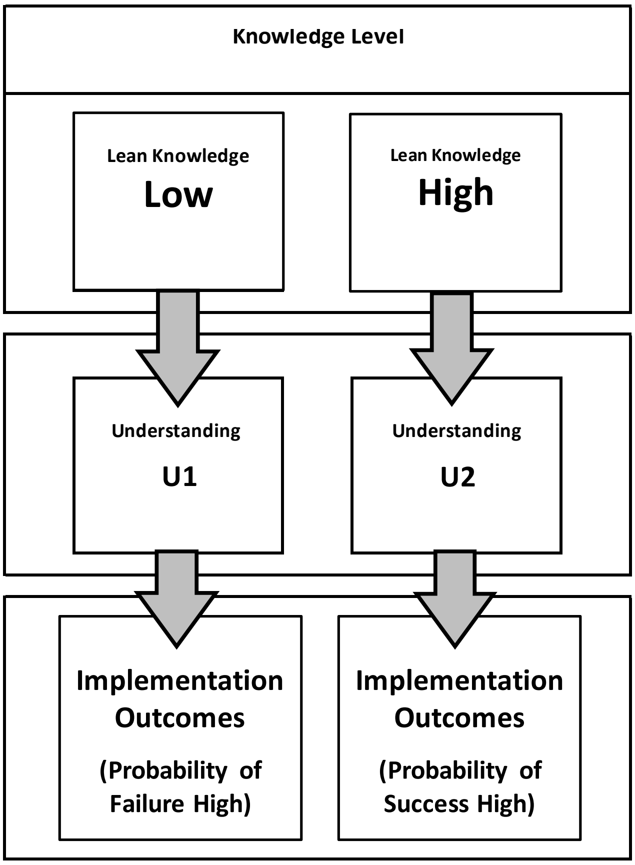

Figure 72 Divergent understanding model: the developing construct of lean knowledge for lean success.

The novel premise in this work is showing divergent understanding. This proposes that the benefit of increased lean knowledge is not merely associated with a general increased understanding of the matter but rather a different understanding. In alternative terms; the definition of lean changes significantly with increased lean knowledge, it becomes significantly different. It was believed these understandings formed a kind of mediating relationship with success and failure. Figure 72 shows the developed construct. It includes the level of knowledge and different understandings U1 and U2.[112]

6.6.2 Systematic Interpretation of the Data

Two Definitions of Lean

To better communicate the findings, two definitions (understandings or views) of lean were extracted from the data. The factor analysis shows that as knowledge develops a different understanding of lean develops towards a holistic view. A secondary construct, lean as tools processes and repacking of old methods

[112] This hypothesis was tested and supported by the SEM (p. 39) showing the mediation of Holistic Lean between knowledge and perceived advantage.

(Tools/Repack) was also present in the data set but it was in an alternate plane. For the interpretation of the data it was determined that:

- Two definitions for lean were sought, one at low knowledge and one at high.
- The construct Tools/Repack describes an alternative view.
- Tools/Repack does not expressly describe the understanding at low levels of lean knowledge.
- In order to define the different understanding by knowledge level, an alternative approach was needed.

The alternative approach involved considering not just the main construct. Linear investigation considering all the *lean understanding* variables was required. Variables were removed if they were not associated with the understanding of lean. The definitions phrases were combined from the question text. The questions text was modified slightly to represent the magnitude of responses seen. Figure 73 shows how these phrases were systematically formed.

		Low Knowledge (Low Familiarity)		**ANOVA (Low to High)**			**High Knowledge (High Familiarity)**	
Variable		**Likert mean**	**Interpretation**	**dF Err**	**F**	**p**	**Likert mean**	**Interpretation**
			Lean …					Lean …
Philos. / Strategy (V058)		2.6	XX (~Moderate - not significant for this variable to be included)	353	33.9	0.0000	3.3	is a business strategy and philosophy,
Waste Elimin. (V053)		2.5	includes waste elimination,	363	51.2	0.0000	3.3	focusing on waste elimination but with
Respecting People (V057)		1.8	XX (~Moderate - not significant for this variable to be included)	331	54.4	0.0000	2.9	respect for the people of the organisation seen in a
Train & Empower (V054)		2.3	XX (~Moderate - not significant for this variable to be included)	356	80.7	0.0000	3.3	strong focus on worker training and empowerment to solve problems.
New Systems/Ways (V056)		2.4	includes new systems and ways of doing things,	361	12.5	0.0005	2.8	It incorporates new systems and ways of doing things
Tools, processes (V051)		2.3	and various tools and processes	359	8.7	0.0033	2.7	It also has tools and processes for productivity improvement.
Needs regularity and focus (V059)		2.7	XX (~Moderate - not significant for this variable to be included)	346	56.6	0.0000	3.5	The implementation process needs a great amount of regularity and focus for sustained success
Competitive Advantage (V062)		2.5	Provides some competitive advantages	356	42.0	0.0000	3.1	Provides a great competitive advantage

Likert Values: 0 = not at all, 1 = small extent, 2 = moderate extent, 3 = great extent, 4 = very great extent
ANOVA typical form F(df effect, df Error)=F p<0.05 is significant
'df error' is indicative of total "sample" size for compared groups (n-2 in this case)
For some variable a moderate response was not accepetd as significant for inclusion in the definition.
For example Philosophy and Strategy (V058) had a moderate Likert value for the low knowledge level. Any introduced method would effect phlosophy and statedgy to some extent, so a moderate effect is not worth methioning in the definition.

Figure 73 The systematic formation of the two definitions of lean.

Figure 73 shows mean Likert values by knowledge level, i.e. low and high familiarity with lean. ANOVA shows the effect size (F) and significance (p). Mean Likert values are interpreted for the definition phrases. For some variables, a moderate level of response was not accepted into the definitions. Philosophy and

Strategy (V058) had a moderate mean of 2.6 at low knowledge. Any introduced method can be assumed to impact strategy to some extent. For this variable a moderate response does not especially define the method and should not be mentioned in the definition; this was also the case for training and empowerment, respecting people, and needs regularity and focus. Alternatively, waste elimination (V053) is more specific to lean terminology. It was retained in the low knowledge definition, even though its mean was 2.5. Which variables formed the higher knowledge view was confirmed by the most significant ANOVA effects and the previous factor analysis. Variables that showed little difference formed the baseline view at low knowledge levels. The baseline understanding included lean as waste elimination, new systems and ways and various tools and processes for productivity improvement. This view was termed the baseline as the Holistic Factors are added to it in order to form the higher view of lean.

For those of lower knowledge, lean was defined:

- Lean includes various tools and processes, as well as systems and ways for process improvement including waste elimination.

The higher, holistic understanding of lean is much more emphatic describing definitely what lean is and has; it was:

- Lean is a business strategy and philosophy. It incorporates new systems and ways of doing things, focusing on waste elimination but with definite respect for the people of the organisation. This is seen in a strong focus on worker training and empowerment to solve problems. It also has tools and processes for productivity improvement.

This second definition is considered as a higher and holistic view because it presents lean as a philosophy and strategy that encompasses all of an organisation. Whether value creation should have been included more emphatically in the survey questions is debatable. Truly defining waste requires understanding the customer perspective of value to avoid mere cost reduction and minimisation of value. In a proper sense, waste is relative to and implies value is understood. Four participant’s text comments did address value creation. These comments were: “efficiency is relative to current state and there comes a point when improvement actually diminishes eventual value”, “understand the end-to-end value for the customer”, “lean creates a value stream and focuses on the customer”, and “Do the easiest first. Find something of value that will definitely work”. The low frequency of these comments indicate that this was not a missing in the definition formed, i.e. the common understanding of lean and the survey adequately covered the key concepts. It was the researchers view that waste elimination implies value and is implicit in the above definition. Future research could investigate the understanding of lean as focusing on value creation, to see whether or how much this concept has infiltrated at the practitioner level.

The lower and higher knowledge definitions formed were built into the framework.

Framework Interpretation

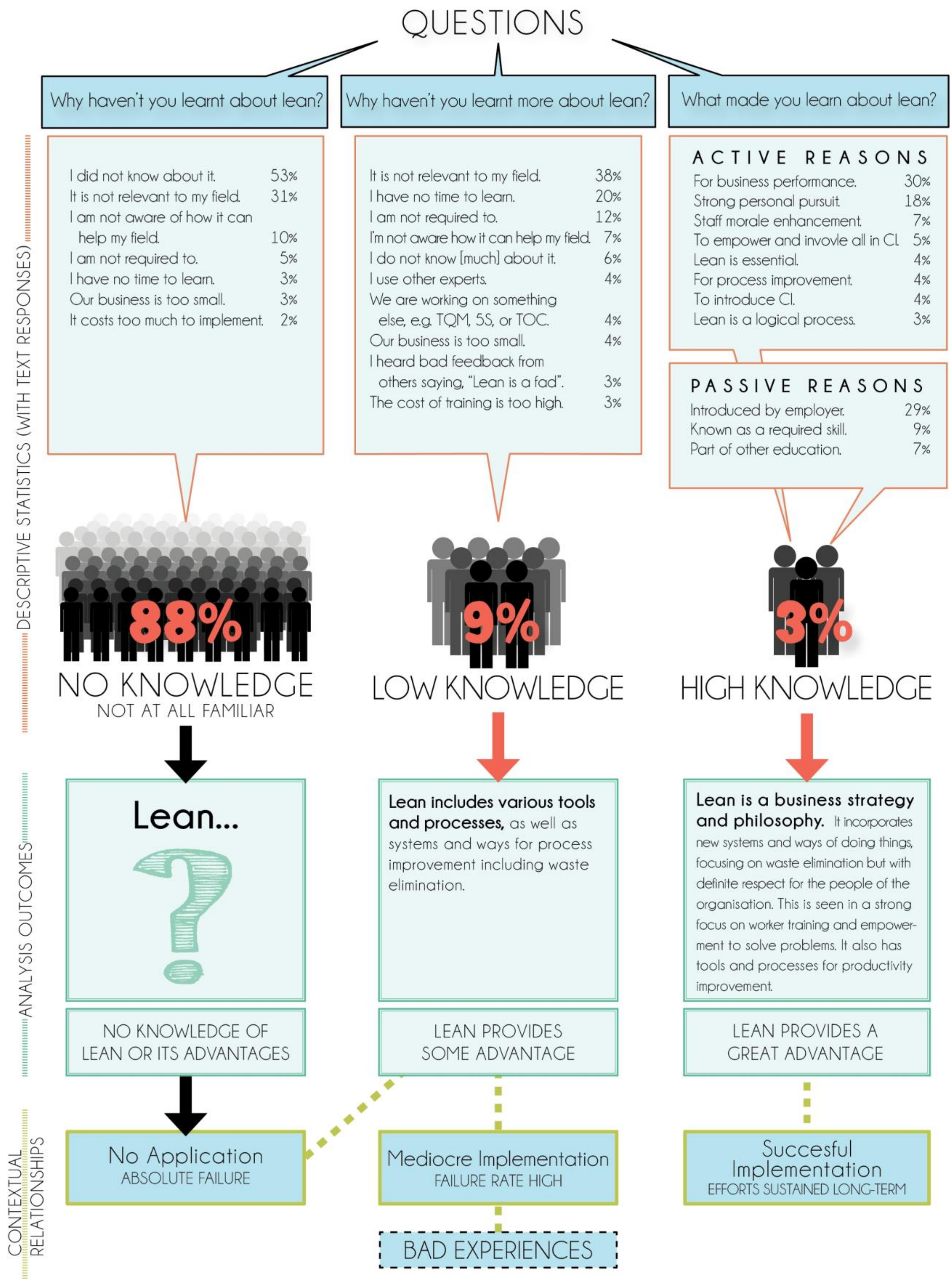

Figure 74 Model of lean knowledge, a systematic interpretation of the data. The framework shows the influences on lean knowledge, the different understandings of lean, and the relationship with success.

The systematic interpretation of the data, Figure 74, presents the differences by knowledge level, starting with the influences on lean knowledge. A grand, 88% of people are in the no knowledge category. Their reasons for not pursing lean knowledge include simply not knowing about it (53%) and not being aware how it can help (10%). These are logical responses. More surprising is the 31% who said lean was not relevant to their field, even though they indicated being not familiar with lean. This implies self-deception. The 88% who don't know about lean, are totally unaware of its advantages and therefore would never apply lean, i.e. absolute failure.

Participants of low lean knowledge make up 9% of the general population or ~75%[113] of those with lean knowledge. Although they knew about lean, 38% felt it was not relevant to their field. They typically define lean as tools and processes, new systems and ways for productivity improvement. They do not see the more holistic side of lean and only associate it with some, moderate benefits. If they apply lean, it is likely to be with mixed levels of success. Participants in the low knowledge category (who may think that they understand lean) are likely misguided without a proper and holistic view of true lean. This is a generalisation but it is based on the significant correlations of lean familiarity with the variables for the understanding of lean. According to a poor definition of lean, lean would be applied but in a misguided form. These implementations may be driven by a consultant and have a tools focus. The outcome may be initial success but ultimately failure to sustain[114] is likely. Some may then seek improvement on their failed approach and shift towards the more balanced and holistic approach to lean. This has been observed in NZ (Gardiner, 2011; Murti, 2009). Unfortunately, in many, bad attitudes toward lean and other similar organisational changes develop (Bordia et al., 2011). An outcome is the thought that lean doesn't work and is just a fad; this came out in the textural responses.

The high knowledge level category makes up 3% of the population, or ~25% of those who have knowledge of lean. Their active reasons for pursuing lean knowledge included seeking business performance gains 30% and strong personal pursuit of excellence 18%. Alternatively, passive exposure from employment made up 29%, and 9% picked up lean merely as a required skill, without signs of passion or drive for improvement. Only 7% were introduced to lean through education sources. Others sought staff morale, empowerment, and continuous improvement (CI). Lean was seen as essential by 4% and as a logical process by 3%.

In the high knowledge category, lean is viewed holistically. The focus is not only tools, systems and ways for process improvement, but also taking lean as the business philosophy and strategy and respecting people, as well as focusing on training and empowerment of employees. Lean provides great benefits in the eyes of

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[113] The value is given as aapproximate due to lack of resolution sample, i.e. the general population surveyed using Facebook distribution.

[114] This was contextualised by case studies from this work and others (Goodyer et al., 2011; Hines, Found, Griffiths, & Harrison, 2008; Schmidt, 2011; J. P. Womack, 2007).

these people, i.e. a great competitive advantage. Their understanding is in line with the lean iceberg model and the development of a learning organisation, one that is self-propelling (Hines et al., 2011). A self-propelling or self-improving organisation has the advantages of a culture of ongoing improvement (supported by systems). This does more than sustain an initial improvement by achieving continuous improvement with emergent change. Unfortunately, it is only a small 3% of the population, ¼ of those with lean knowledge, that are associated this view. It is only this portion that sees the advantages, and by inference are in line to reap the true benefits of lean.

6.7 Support for Hypotheses

Hypothesis 1: The major success and failure factor for lean is leadership knowledge.

In this chapter, different views of lean were analysed as a step toward addressing leadership knowledge as a success factor. Although this analysis did not expressly address leadership levels, some inference can be made to the effect of knowledge on leaderships understanding and their achieving lean's advantages. Sub hypotheses were formed and tested by SEM.

Hypothesis H1 implied that increasing knowledge develops a different understanding of lean, a holistic view. And this understanding mediates between knowledge and the benefits of lean. The ultimate testing of this hypothesis was by SEM. The outcome confirmed H1:

H1 The positive effect of lean *Knowledge* on the *Perceived Advantage* of lean is mediated by the Holistic view of lean.

An alternative view of lean was uncovered by EFA. This also was shown to have a relationship with lean knowledge in testing H3.

H3 The view of lean as tools and a repackaging of other methods (Tools/Repack) has a negative relationship with lean Knowledge**.**

There was a weak negative relationship (-0.17), only accounting for a small amount of variance (3%) of the lean Tools/Repack construct.

A weak insignificant relationship (-0.11) was observed between the perceived advantages and this view of lean, rejecting H2.

~~**H2** The view of lean as tools and repackaging of other methods, Tools/Repack has a negative relationship with Perceived Advantage of lean.~~

The data set had 193 complete responses, six times the rule of thumb minimum (30). There may be a significant weak relationship observed with an extremely large data set and highly defined construct, but this is doubtful.

6.8 Implications and Additional Findings

The implications of this section are summarised with the outcomes below. The full interpretation of this analysis is included with the findings of Questionnaire Two in the final discussion (p. 299). There were also many ancillary findings to this analysis that have been placed in the appendix. Refer to Second Tier Outcomes, page 378.

6.8.1 Implications to this Work

The work manifested the different understandings of lean, the current 'best' practitioner understanding, and the perceived success factors. The importance of knowledge had begun to be addressed, however inferences to success were made from opinion of leans advantage only. And although the influence of lean knowledge was addressed in general, it was not expressly linked to leadership levels.

The implications to this work were:

- There was the need of specific case study analysis to further validate and develop this research on success factors, including the specific role of management knowledge.
- Regarding the importance of leadership, the role of consultants in lean success also needed to be defined.

The second questionnaire experiment provided case data for addressing these needs.

6.9 Outcomes

An understanding of the relationship between lean knowledge and lean success was developed. A framework was built to represent these insights (Figure 74).

Results indicated that lean provides a competitive advantage but is failing to deliver, not because lean itself is flawed but because of the way it is understood and applied. Those at a low knowledge level of lean understand lean differently than those of higher knowledge. That is, lean is not merely understood more, but two definitions of lean exist. The analysis indicated the following definition for those with low knowledge:

- Lean includes various tools and processes, as well as systems and ways for process improvement including waste elimination.

Increased knowledge of lean was associated with a higher, holistic view of lean:

- Lean is a business strategy and philosophy. It incorporates new systems and ways of doing things, focusing on waste elimination but with definite respect for the people of the organisation. This is seen in a strong focus on worker training and empowerment to solve problems. It also has tools and processes for productivity improvement.

Increased knowledge of lean also correlated with a perceived competitive advantage. This can be contextualised as:

- There are significant benefits to lean that are not being realised because of the lack of understanding. A learning approach to lean implementation should be taken.

Development of the holistic view is currently associated with high familiarity and extensive experience. This needs to change. The holistic view is not especially complicated as a concept and need not take a long time to learn. Unfortunately, the majority take lean from the tools and process perspective. This inadequate tacit knowledge is proliferated through industry; there is a critical mass moving in the wrong direction. Lean education needs further development and propagation. Government support through education would be more advantageous than providing funding for consultants. Education programmes would be supported by further empirical proof of the benefits of holistic lean and a simple framework for understanding it.

7. Correlation Experiment Two—Factors for Sustained Improvement

The second experiment involved implementation case data, i.e. the actions taken and the outcomes observed. Questionnaire distribution targeted practitioners who had embarked on implementations, successful or unsuccessful.

The purpose was to provide an empirical analysis of the contextualised factors. The analysis emphasised the relative importance of variables and the relationships between them. Specific hypotheses are listed.

Addressing the factor of leadership knowledge:

> ***Hypothesis 1: The major success and failure factor for lean is leadership knowledge.***

Addressing the use of consultants and methods as opposed to leadership aspects:

> ***Hypothesis 2: Consultants and the tools or methods of lean are secondary. The primary aspects are leadership and enabling development.***

Regarding situational variables:

> ***Hypothesis 3: The key success factors for lean do not differ due to business size, and product mix.***

The variable of business size is particularly important for the New Zealand in regards to SMEs.

7.1 Approach

A web based questionnaire was used to gather the implementation data. The survey design intended to be as brief as possible to maximise responses whist including all key variables (Fan & Yan, 2010). Key factors and popular methods were covered by 87 questions.[115] Additional questions covered control variables including participant characteristics. Room for "other" and text responses allowed flexibility and avoidance of confirmation bias.

The use of e-marketing techniques gathered:

> 1253 responses from over 44 countries

This allowed flexibility for analysis of various cross sections.

This chapter focuses on data characteristics and linear analysis. More advanced hypothesis testing with structural equation modelling (SEM) is presented in 8. Results from SEM, page 239.

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[115] See Figure 79 for abbreviated variables. The full question are in the appendix, from page 497. The comprehensive cover of the factors and case related questions necessitated a large survey. Additionally, some variables were tested with multiple questions. As example, the survey asked how much the implementation was sustained then, for comparison, it asked the extent management pressure was still required

7.2 Data Characteristics

The majority of response came from online discussion groups, through posts and personal communication with group members (Figure 75). Approximately 6400 personal messages were sent with an acceptable response rate of 22% total and 11% useable[116] (Curtin et al., 2000; Sheehan, 2001; Visser et al., 1996). This response rate compares well with similar large-sample operations surveys (Ward & Zhou, 2006), e.g. 11% (T. A. Boyle et al., 2011) and 7% (Ward & Zhou, 2006). Personal communication (direct contact) delivered 1022 (80%) of the responses. Of the 44 countries represented, 21of them had 8 or more cases (Figure 76).

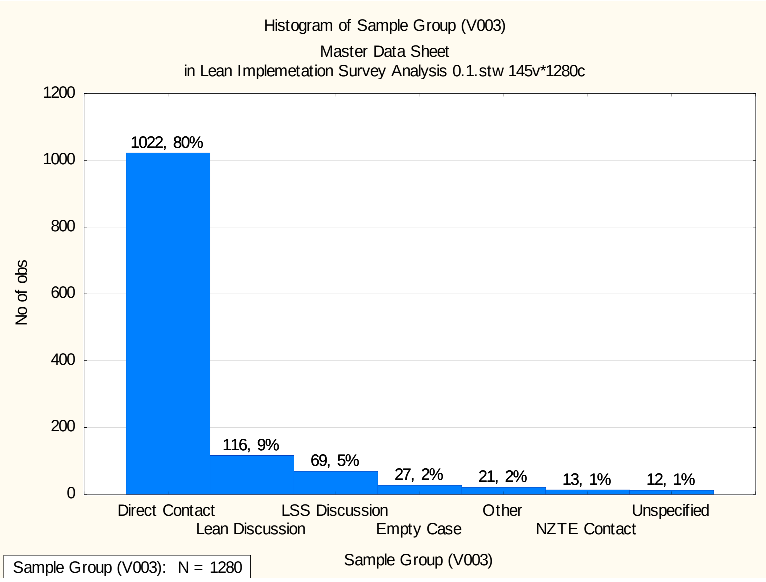

Figure 75 Sample groups for questionnaire Two (Pareto chart)

[116] Response rates are approximate. An exact response rate was difficult to calculate due to advertisement in discussion groups and some secondary referrals. Secondary referrals were appropriate as anyone with the adequate experience was welcomed to fill the survey.

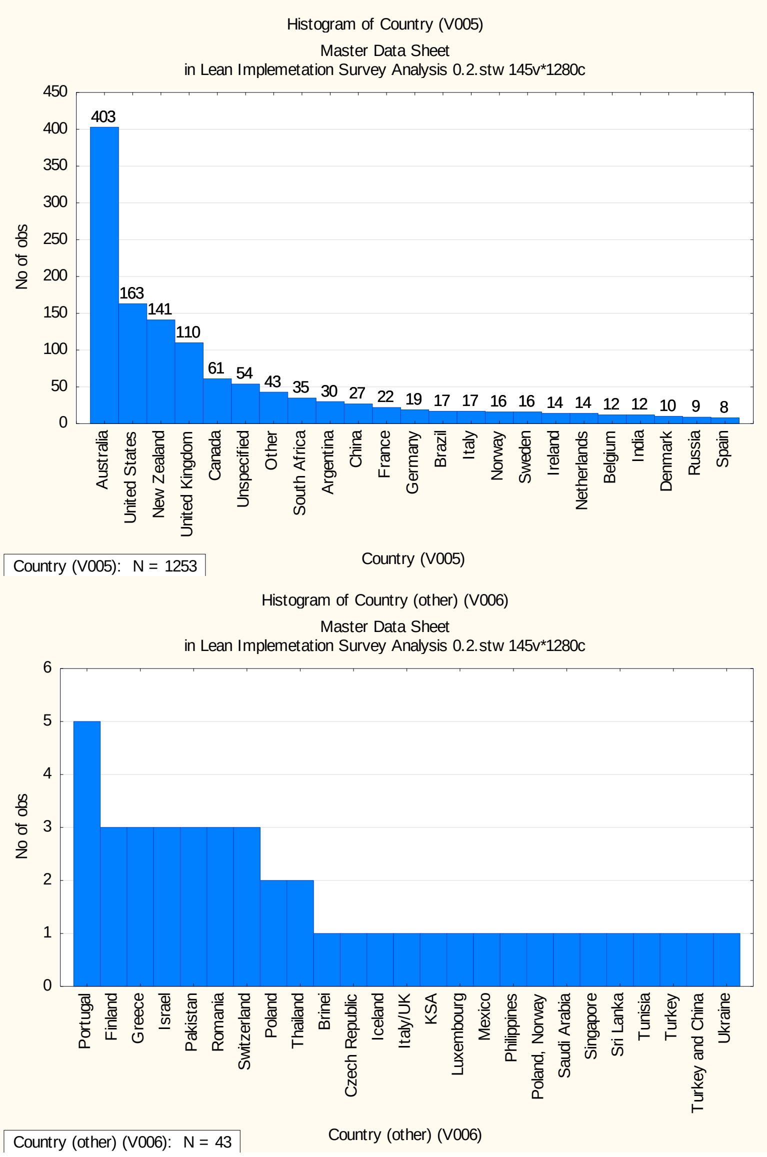

Figure 76 Countries represented (all data)

Work experience amongst participants was reasonably high, 60% had 15 or more years of experience (Figure 77). Logically, experience with lean implementation was high, 60% being experienced to a great or very great extent (Figure 78). Methodologies by order of experience were lean, quality systems, TOC, Agile Manufacturing, and Agile for IT (ref. Figure 293 through Figure 296, p. 458).

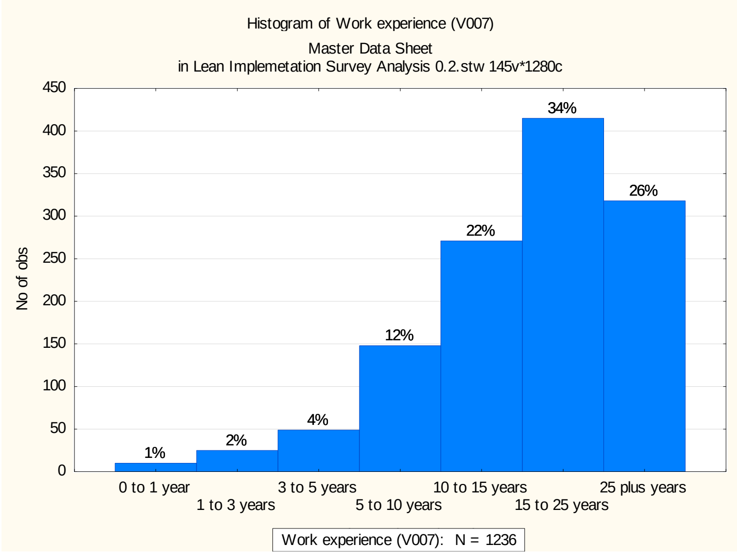

Figure 77 Participant work experience (all data)

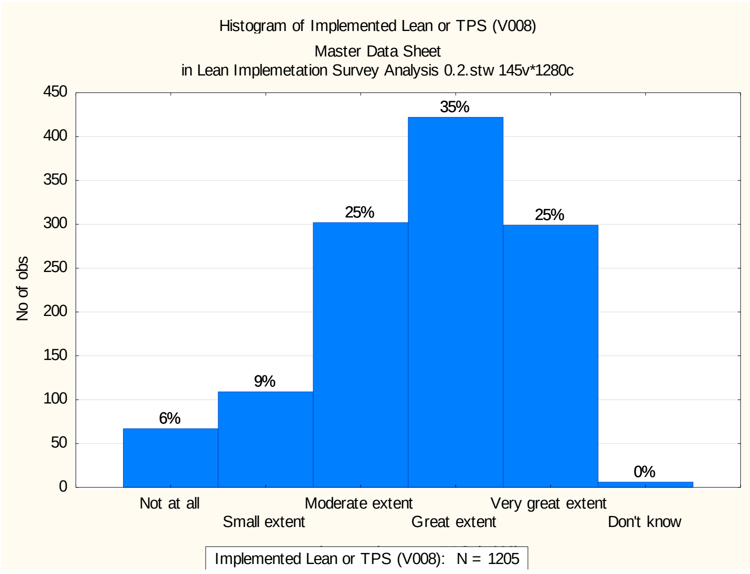

Figure 78 Experience implementing Lean or TPS (all data)

7.2.1 Measured Variables

Measures (questions[115]) were split into three survey sections: General Demographics, Implementation Case, and Lean Knowledge Survey.[117] Addition variables were calculated and coded from text responses.[118] Variables were typically 5 point Likert scales except for text responses and demographics. See abbreviated variable list, Figure 79.

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[117] The major part of this work was in the Implementation Case questions. The Lean Knowledge Survey questions repeated the first survey for reference.

[118] For example, whether or not a consultant was used at all (V133) was inferred from the other consultant related variables (V035, V065 and V073). The Completeness (V144) variable was calculated by the percentage of the key implementation questions that were answered and used to select sufficiently complete cases for analysis. The variable Invalid (V141) was for responses to be removed from study. The reason they were to be removed was recorded in V142 (see Figure 297, p. 264).

A) General Demographics
Case ID (V001)
Completed (V002)
Sample Group (V003)
Sample Group (other) (V004)
Country (V005)
Country (other) (V006)
Work experience (V007)
Implemented Lean or TPS (V008)
Implemented Theory of Constraints (V009)
Implemented Agile (Mfg.) (V010)
Implemented Agile (IT) (V011)
Implemented Quality Systems (V012)
B) Lean Implementation Case
Case Method (V013)
Combination/other (V014)
Competitive Advantage (V015)
Performance Enhanced (V016)
Staff Morale Incr. (V017)
Key Outcomes Comment (V018)
Role (V019)
Role (other) (V020)
Was Leader (V021)
Was Leader (Other) (V022)
Industry (V023)
Industry (Other) (V024)
Org. Classification (V025)
Org. Classification (clarification) (V026)
Staff No. (V027)
Implementation Run time (V028)
Org. Flatness (V029)
Org. Flatness (other) (V030)
Journey View (V031)
Momentum Constant (V032)
Started Well (V033)
Emphasis Process Improvement (V034)
Implementation by consultants (V035)
Management Commitment (V036)
New Culture Emphasis (V037)
New Cult Developed (V038)
Staff in Planning (V039)
Sustained Implementation (V040)
Worker Initiatives (V041)
Used Incentives (V042)
Driven by External Support (V043)
Developed Self-improving Org. (V044)
Financial Situation (V045)
Financial (Clarification) (V046)
Management Planned Well (V047)
Easy for suggestion/improvements (V048)
Culture Initial priority (V049)
Management - Effective Comm. Process (V050)
Management - Vivid Comm. Strategy/Vis] (V051)
Management - Comm. Staff Role (Alignment) (V052)
Management - Vivid Comm. Steps of Change (V053)
Management commit. training (V054)
Management had excellent lean knowledge (V055)
Staff Trusted Management (V056)
Involved all Staff (V057)
Lean/flow accounting (V058)
Flow focus (vs utilisation) (V059)
Management Pressure was needed (V060)
Management Press still Needed (V061)
Staff Capability (V062)
Technology Capability (V063)
Management Capability (V064)
Consultant Capability (V065)
Implementation Leader Capability (V066)
Management understood tools/methods (V067)
Management understood as a new culture/philosophy (V068)
Groups of Positive Staff (V069)
Easy to maintain momentum (V070)
Fear as a Motivator (V071)
Small wins prominent (V072)
Consultants as a coach.(V073)
New staff identity developed (V074)
Growth mindset (can learn/improve) (V075)
Staff warned of the struggle (V076)
Guiding coalition supporting(V077)
Program/Structure/Regularity (V078)
Individual support in adjusting (V079)
Standard work developed (V080)
Staff meetings(V081)
Performance review/support (V082)
Implementation review and planning (V083)
PCMH (Previous bad experiences) (V084)
Information Systems (V085)
5S System (V086)
Just In Time Manufacture (V087)
A3 Management, or Nemawashi or Catchball process (V088)
Total Productive Maintenance (V089)
Kaizen (Kaikaku) Improvement Events (V090)
5 Whys (V091)
Simple problem solving(V092)
Defining Value (V093)
Pull Systems (V094)
Kanban (V095)
Statistical Methods (V096)
Mapping Value Stream (V097)
Visual Systems (V098)
Root Cause Analysis (V099)
Engaging suppliers (V100)
Engaging customers (V101)
Employees resisted change (V102)
Culture similar or conducive already exists.] (V103)
Staff had KPIs/clear goals (V104)
Management continued. to learn and participate (V105)
Management established lean knowledge at start (V106)
Other factors felt important (V107)
Do differently. (V108)
Significant positive outcomes (V109)
Significant negative outcomes (V110)
Email (V111)
C) Lean Knowledge Survey
Completed survey #1 (V112)
The extent that a manager understands Lean is critical for success. (V113)
In a small organisation, management's understanding is top priority for success. (V114)
Fam. (familiarity with) Lean or TPS (V115)
Fam. Theory of Constraints (V116)
Fam. Agile Manufacturing (V117)
Fam. Agile for IT (V118)
Fam. Quality Systems (V119)
Repacking (V120)
Tools, processes (V121)
Process Eng. (V122)
Waste Elimination (V123)
Train & Empower (V124)
Fragile/Unbuffered (V125)
New Systems/Ways (V126)
Respecting People (V127)
Philosophy/Strategy (V128)
Needs regularity and focus (V129)
New label - Industrial Engineering (V130)
Caused you to learn about Lean (V131)
Final Comment (V132)
Other

Figure 79 Questionnaire Two variables in three sections: General Demographics, Implementation Case, and Lean Knowledge Survey. For full questions see page 500.

7.2.2 Data Quality

Ambiguity and Bias

Survey design played a crucial part in minimising misinterpretation and maintaining data quality. Pilot surveys are regularly used to test design. Confidence in the survey design led to an alternative approach. Rather than pilot, a slow release was used. This allowed for fine modification as feedback returned. As no major changes were required, all pilot data was valid for inclusion in analysis. Thorough screening of all text responses gave confidence that questions were understood correctly. Additionally email correspondence[119] with participants and the gathering of a significantly large data set mitigated these risks.

There were no signs of skew due to self-report. One variable that was particularly vulnerable was Consultant Capability (V065). Significant subjectivity would imply that, a good or bad implementation outcome develops perceptions of how good or bad a consultant was; but there were no significant correlations between consultant use and success (see Consultant Contribution, p.229); this is one indication self-report had no significant effect on quality.

Distribution focused on and received a high number of responses from discussion groups, specifically the Lean Business Systems Group on Linkedin.com. This could have introduced minor bias due to group culture. Discussion groups also favour participants from professional roles as opposed to trade or factory workers. It is unfortunate but an accepted fact, it would be difficult to get many workers to fill in the survey. Typically, the higher levels of hierarchy were more able to fill out the detailed questions, but these views could have a positive bias. These possible minor biases were not observed to cause any detrimental effect on the analysis.

The data gathered gave a range of successful and non-successful instances of implementation with a variety of factors influencing it. Outcome variables were distributed normally, indicating bias was insignificant. Skew would be expected with significant positivity bias.

Non-response bias was difficult to check because of the staged distribution of the survey. There is no reason to believe non-response would impact the data set. Response rate was acceptable at 22% total and 11% useable (Curtin et al., 2000; Sheehan, 2001; Visser et al., 1996), and similar questionnaires showed non-response had no effect (T. A. Boyle et al., 2011; Ward & Zhou, 2006).

With the large data set, it was expected that relative trends would be represented clearly. Even though some individual biases may occur, the large number of cases helps reduce individual bias whilst maintaining general trends.

[119] Participants were given the option to leave contact information. They could either keep answers anonymous or not. Email was used for future amendment of additional question answers to their original set. This was useful to clarify participant answers at the stage of data review.

Approval of Survey Design

Survey design and content were well accepted by participants. Of the 1478 comments made, less than 1% (3) made negative comments[120] about the general survey design. Their limited frequency is supportive of the approach. 13 responses were specifically positive about the survey and many others left general positive comments. 472 participants requested the results and 351 were willing to be contacted further.

7.2.3 Case-wise Screening

Case data was reviewed and adjusted as necessary. This included reading and coding of 1478 text comments (see page 446). Although slower than automated text mining, manual mining allowed common thoughts to be gathered. Comments on implementation outcomes (V018) and factors felt important (V107) were fully coded. Automated word counting was incorporated later to check for method bias. Based on the responses some erroneous cases were removed from the analysis (see Figure 297, p. 459).

Text answers for the main part reinforced existing variables. This showed the survey had good coverage of the pertinent measures. Alternative factors were repeated in text comments however they were typically isolated and with little frequency. Three thoughts were marked as important for future empirical investigation:

- Developing internal expert lean capability i.e. other than management development and general staff involvement (this was partially covered but more detail would benefit).
- Specific cost cutting focus to implementation including extent staff were laid off or lost (although partially covered by fear as a motivator).
- Also specific mention of team focus (although engagement and involvement was part of survey)

Completeness by Case

For completeness case-wise, 85 key variables were identified amongst the implementation data.[121] A histogram of the completeness of these fields (by case) can be seen in Figure 80. For completeness purposes a “Don’t know” answer was reckoned as missing data. Case method (e.g. lean vs. lean six sigma) or industry did not show any significant correlation with completeness (see Figure 81, and Figure 82).

[120] Of 310 participants who made comments, 3 were negative about survey design.

[121] Certain demographics and additional questions were not included.

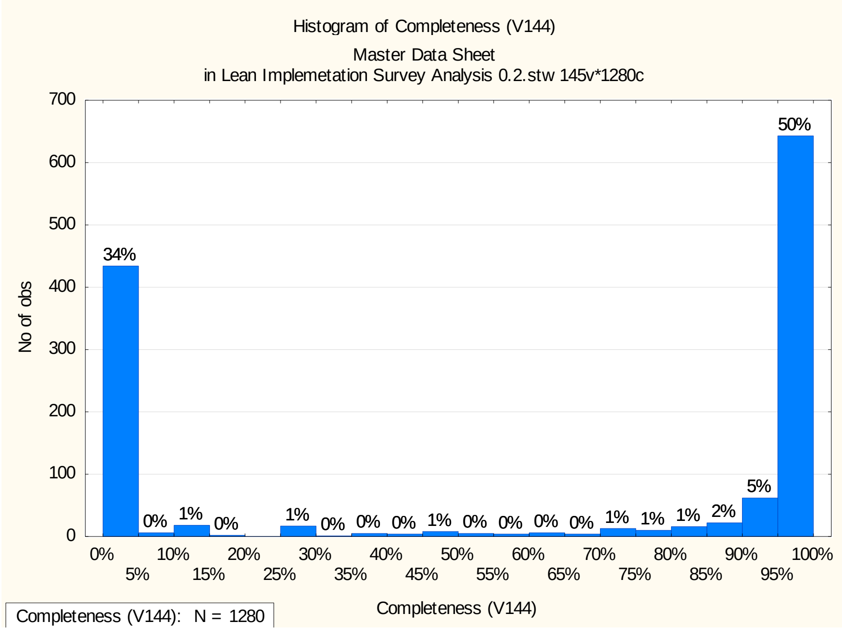


Figure 80 Completeness of key implementation questions (all data)

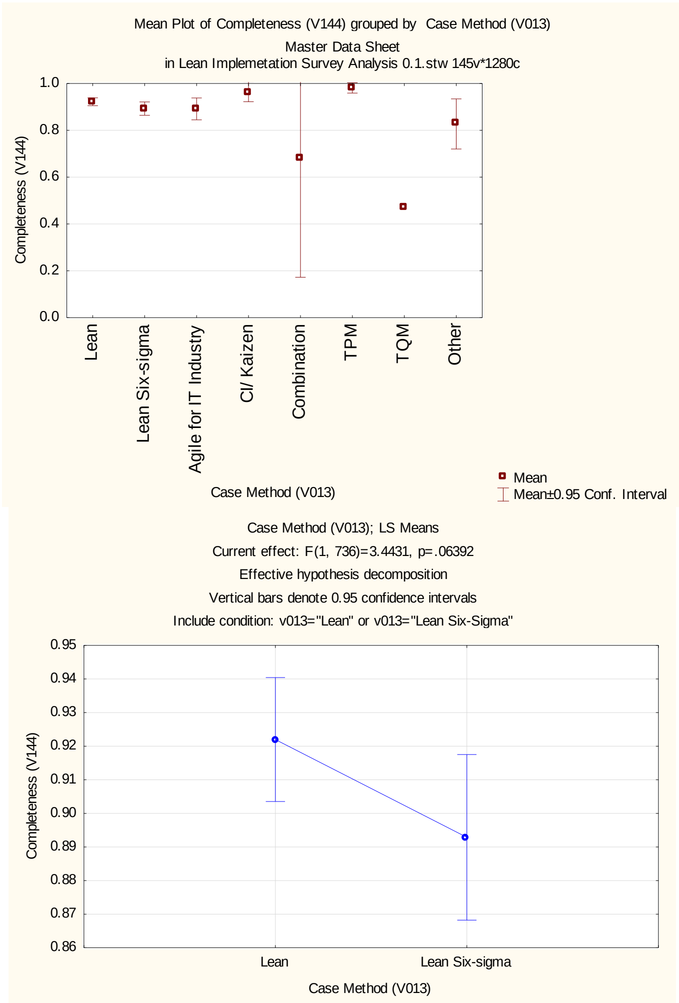


Figure 81 Completeness of key implementation questions by case method chosen (all data)

A comparison between completeness of data for lean cases versus lean six sigma cases is shown in Figure 81. These categories had the most significant data sets. It was thought that if lean six sigma implementations were more temporal project based their participants would be less able to complete the questions. The mean completeness for lean cases was 3% higher than lean six sigma. This was an insignificant result. ANOVA showed, $F(1,736)=3$, $p= 0.06$ i.e. $p>0.05$. Additionally no significant differences were observed in completeness by industry (Figure 82).

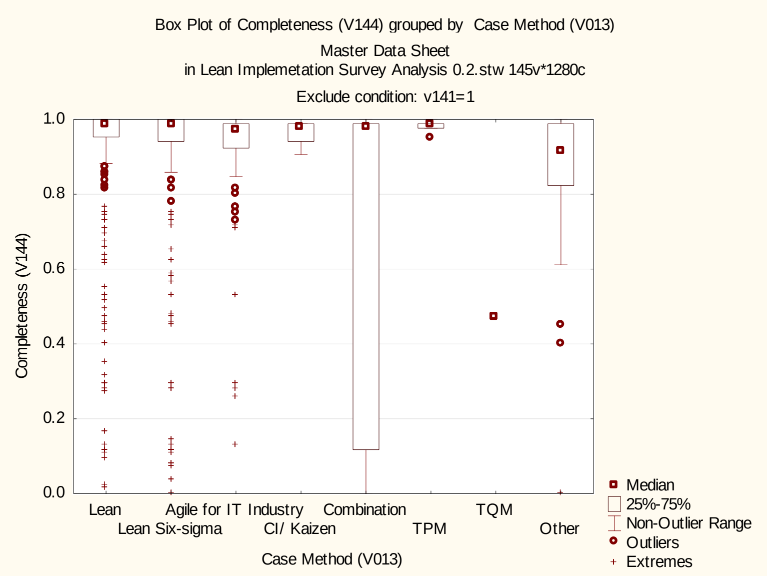


Figure 82 Completeness of implementation questions by industry (box plot). Differences between industries were deemed insignificant.

Case Selection: Lean and Lean Six Sigma, 2 years + run-time, 88.5% complete

Lean methods lean & lean six sigma provided the largest amount of cases (393) and were the focus of this work. The following case selection[122] was applied to analysis.

- Lean and lean six sigma cases with,
- 88.5%+ complete implementation data (90%, Joseph F Hair, 2010) .
- Exclude cases marked invalid (v141).[123]
- Exclude cases less than two years run-time.

Implementations of less than two years run-time were removed to avoid unproven cases and their undue excitement. Womack & Jones' Action Plan (2003, p. 247) suggest that a full transition: leaning suppliers and customers, global strategy, and full bottom-up change by the end of year 5, with internal success achieved at earlier stages. Additional considerations were, first, Success in sustainability is a give-in if the implementation has been running too long. Second, with long run-times particular struggles or wins may not

[122] The below coding is observed in the chart headers:

Include condition: v144>.885 and (v013="Lean" or v013="Lean Six-Sigma")

Exclude condition: v141=1 or v28="0 to 1 year" or v28="1 to 2 years"

[123] Invalid (V141) was for responses to be removed from study. The reason they were to be removed was recorded in V142 (see Figure 297, p. 264).

be as clear as those more recently engaged. Finally, capturing short to mid-term gains is also necessary where immediate survival is a concern. Therefore a two year runtime was deemed acceptable.

Response Deviation

The standard deviations of 80 Likert questions were reviewed.[124] There was only four cases with Std. Dev. <0.67 and a minimum of 0.52. Reviewing actual values, these responses seemed meaningful and made up only 1.0 % of the cases. No cases were removed due to low variation.

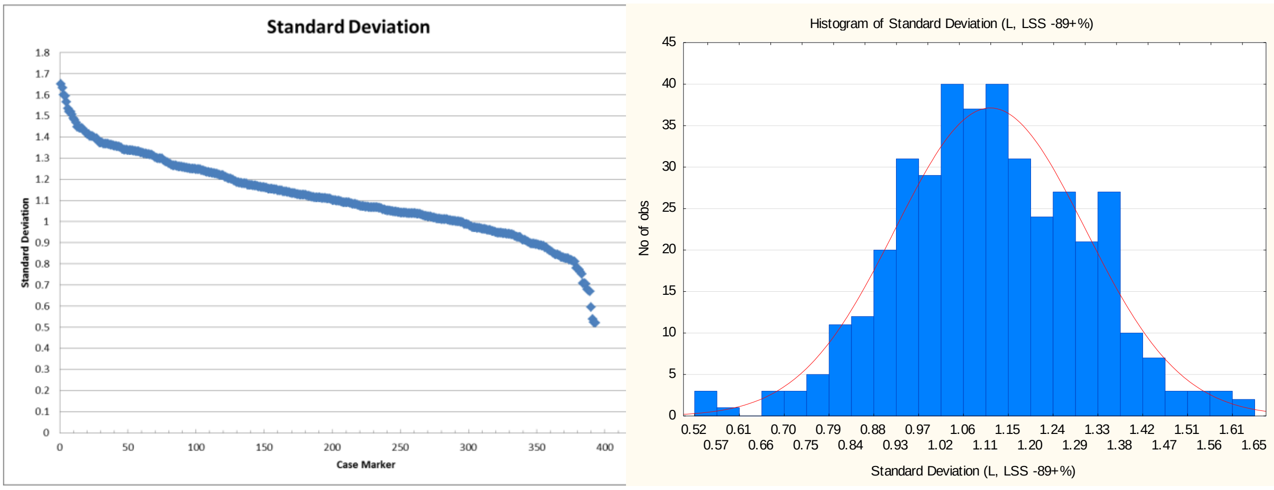


Figure 83 Case-wise standard deviation of responses scatterplot and histogram.

7.2.4 Variable-wise Screening

Completeness by Variable

Inspection identified missing data was randomly distributed through most variables. Most raised no concern with over 90% complete data by variable. Where data was missing it is likely the participant did not want to disclose the information or did not know the answer. Consultant Capability (V065) showed the most missing data (28%), being 72% completed (Figure 84). As in some cases consultants were not used the "not at all" responses became ambiguous. The consultant variables were analysed in detail with a logic table. The detailed investigation is seen in the appendix, page. 440. A third variable Consultant Use (V133) was inferred and coded yes or no. Consultants were considered individually in the analysis (see Consultant Contribution, p. 229).

[124] Standard deviation helps inform whether a participant answered meaningfully of just clicked through the survey.

Variable	Cases Answered	Missing Data
Total Cases	716	
Pull Systems (V094)	690	4%
Just In Time Manufacture (V087)	689	4%
Consultants as a coach(V073)	686	4%
Sustained Implementation(V040)	684	4%
Financial Situation (V045)	683	5%
Management Pressure still needed (V061)	683	5%
Total Productive Maintenance (V089)	680	5%
PCMH (Previous bad experiences) (V084)	679	5%
Implementation review and planning (V083)	671	6%
Lean/flow accounting (V058)	662	8%
Performance review/support (V082)	652	9%
A3 Management, or Nemawashi or Catchball process (V088)	649	9%
Consultant Capability (V065)	519	28%

Figure 84 Sparse variables: the percentage of missing data for the most sparse variables.

Statistical Assumptions

Further screening of the data was by visual inspection of plots, typically histograms.[125] Visual inspection was deemed more appropriate and pragmatic than statistical tests disconnected from reality (Hill & Lewicki, 2005). A basic assumption across many of the statistical methods is linearity and normality. Most of the data came from textural ordinal variables arranged as 5 point Likert scales. Likert scales do not lend themselves to perfect normal distributions but the majority of the data was deemed acceptable for proposed methods. The data set was reasonably large so the *central limit theorem* supported the assumption. Fortunately the methods chosen are also fairly robust for deviation, e.g. ANOVA and PLS-SEM (see method p. 81).

Some variables did exhibit some kurtosis or skew i.e. Implementation by Consultant (V035), Management Commitment (V036), Lean/flow Accounting (V058), Information Systems (V085), and visual systems (V098). Methods were deemed robust enough to handle these variations. More extreme and concerning variables of poor distribution were External Support (V043), Fear as a Motivator (V071), and A3 management or Nemawashi or Catchball Process (V088). These variables were over represented by "not at

[125] Additional to checking statistical assumptions, screening could identify important variables that would otherwise be unnoticed. A certain variable (e.g. a tool or method) may show a lot of skew. It could be present in both successful and unsuccessful cases but with little variance. This means it would not be a good predictor, it does not mean it is not important for success. No such cases were found.

all" responses. The relationships between these variables and key outputs was analysed with the "not at all" responses removed. One correlation increased but was not significant ($r<0.2$, $p=0.03$), see appendix page 488 for detailed analysis.

7.2.5 Output Variable Review

The analysis utilised output (dependent or response) variables for linear regression and formation of latent variable scales (SEM). The output variables were:

- Competitive Advantage (V015)
- Performance Enhanced (V016)
- Staff Morale Increased (V017)
- New Cult Developed (V038)
- Sustained Implementation (V040)
- Developed Self-Improving Organisation (V044)
- Management Pressure Still Needed (V061)
- New Staff Identity Developed (V074)
- Employees Resisted Change (V102)

Correlation matrices of output variables showed how closely related they were. Between most outputs good strength was observed, r values between 0.45 and 0.75, and high significance, p typically less than 0.0001. Low negative correlations were found for management pressure needed (V061, $r=-0.13$ to -0.32) and very low for staff resistance (V102, $r=-0.01$ to -0.13), except between themselves, management pressure and staff resistance $r=0.28$. For full matrix by pairwise deletion see page 446.

Best Representative of Success

The output that best represents success was investigated. Although this research speaks of sustained instances of lean, the variable Sustained Implementation (V040) is misleading. If an implementation was sustained it is important that what was sustained actually benefited the business. Likewise the goal is not merely to develop a new culture or increase staff morale but the sustained advantages of lean to improve the business.

> An ideal output is a perfect mediator between business performance improvement and a sustained implementation.

The first survey asked whether lean provides a competitive advantage. Some feel lean is not a competitive advantage but a necessity. To remove ambiguity the implementation survey additionally asked "Has business performance improved?" (Performance Enhanced, V016). This was qualified as below:

> "*By performance we mean an improvement better than would have otherwise been expected. A performance unachievable just by merely adding more resources. This includes doing more or better than previously possible (e.g. financial performance, productivity, quality or delivery).*"

The benefit of Lean may be different from business to business dependant on situational variables. For one business it may mean the increased profits for another it may mean merely staying in business by being able to deliver the quality required, i.e. not losing business. This variable provided representation of the advantage of lean on the business.

In the correlation matrix below (Figure 85) Developed Self-improving Organisation had a much stronger correlation with “Sustained Implementation” than other key output variables. It’s correlation with Performance Enhanced (V016) was only slightly less than the strongest correlation, New Culture Developed (V038). The variable Developed a Self-improving Organisation better represents a successful lean implementation than a New Culture Developed (V038). This is similar to a self-propelling organisation (the vision for Cogent Power in Hines et al., 2008, p. 28). Self-improving represents the new culture of lean in specific terms.

	Performance Enhanced (V016)	**New Culture Developed (V038)**	**Sustained Implementati on (V040)**	**Developed Self-improving Org. (V044)**	**Staff Morale Incr. (V017)**
Performance Enhanced (V016)	1.00				
New Cult Developed (V038)	**0.60**	1.00			
Sustained Implementation (V040)	0.52	0.59	1.00		
Developed Self-improving Organisation (V044)	0.58	**0.67**	**0.65**	1.00	
Staff Morale Increased (V017)	0.55	0.50	0.45	0.47	1.00

Correlations are significant to $p < 0.00000001$
Include condition: v144>.885 and (v013="Lean" or v013="Lean Six-Sigma")
Exclude condition: v141=1 or v28="0 to 1 year" or v28="1 to 2 years"

Figure 85 Key output variable correlations: comparing correlations between Performance Enhanced (V016), New Cult Developed (V038), Sustained Implementation (V040), Developed Self-improving Org. (V044), and Staff Morale Incr. (V017). Strongest correlations are shown in bold font.

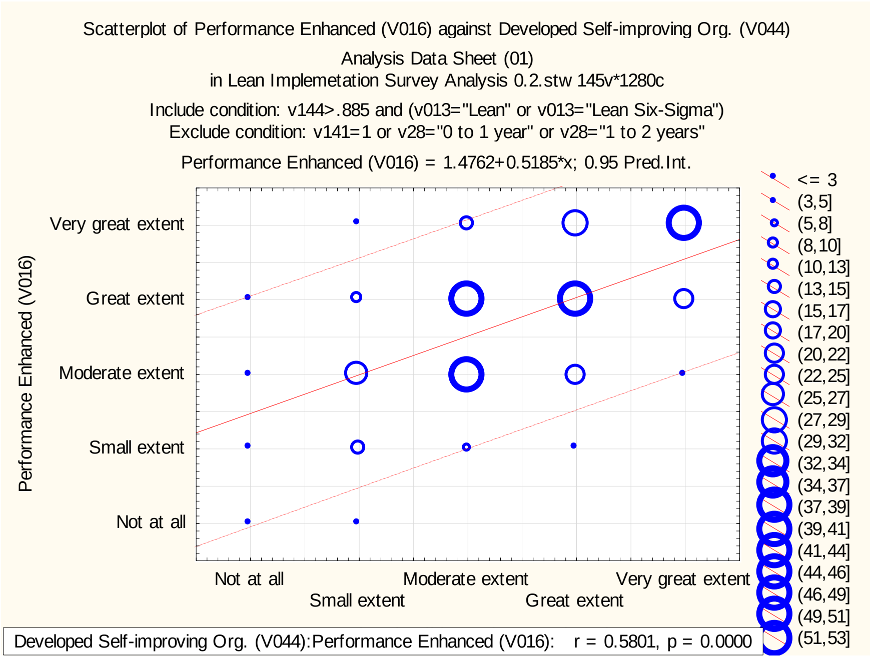


Figure 86 Performance Enhanced (V016) vs. Developed Self-improving Org. (V044) for the lean and lean six sigma cases.

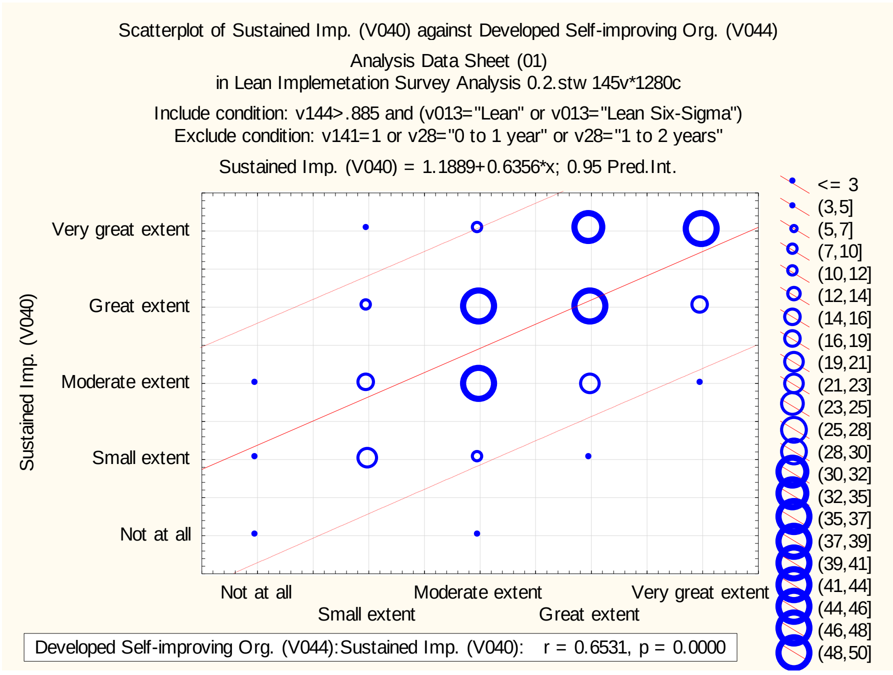


Figure 87 Sustained Imp. (V040) vs. Developed Self-improving Org. (V044) for the lean and lean six sigma cases.

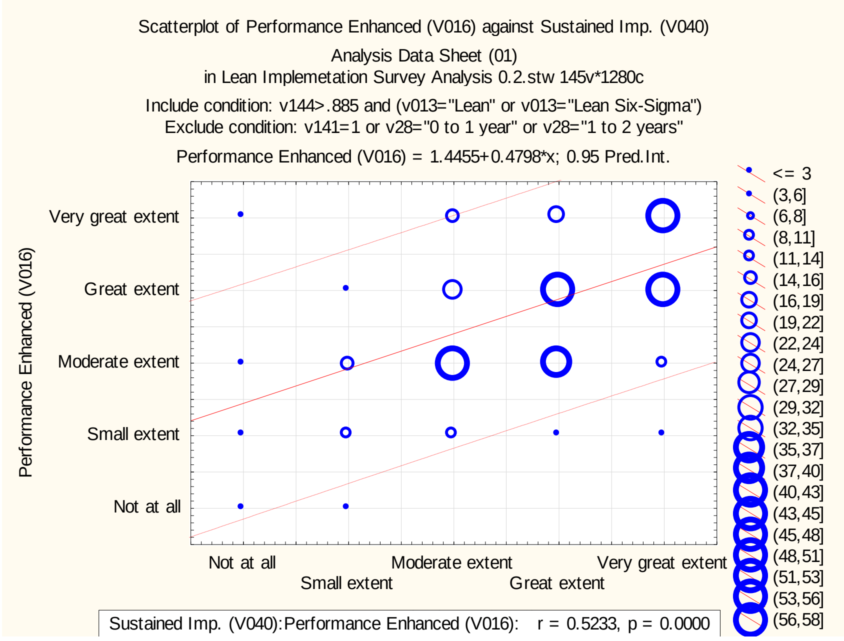


Figure 88 Performance Enhanced (V016) vs. Sustained Imp. (V040) for the lean and lean six sigma cases.

The strength of Self-Improving Org. (V044) as a predictor of success can be seen in the frequency bubble plots Figure 86, Figure 87, and Figure 88. These charts show that V044 has greater weighting towards success (performance or sustainability) than the other output variables. Plots show performance occurred in some cases without developing a self-improving organisation but in all cases a self-improving organisation was built performance enhancement was achieved. This result indicates:

- Lean implementations that produce a self-improving organisation will be successful (i.e. providing business performance in a sustained implementation). This defines the balance between being overly tool and process focused versus culture worship.
- Self-Improving Org. (V044) is a very good indicator of success in this work.

Categorical Success Variable

A binary, yes – no, success variable was developed for categorical analysis, Implementation Success (V162), a mix of high-performance and sustainability determined as:

V016 Performance Enhanced = Great to Very Great Extent

And:

And V040 Sustained implementation = Great to Very Great Extent

To ensure a continuous improvement culture had been embedded an additional filter was:

V044 Self-improving Org. = Moderate to Very Great Extent

7.3 Descriptive Statistics

The demographics for this analysis set are presented in the below figures.[126] The set included 393 cases distributed 69% lean and 31% lean six sigma. 25% of the cases had run for greater than 5 years. Of the countries represented, the majority of participants were from Australia (33%), and New Zealand (13%) followed by the United States (11%) and the United Kingdom (11%). 63% of the cases came from manufacturing; this is appropriate for the main focus of this work. High volume, medium volume, low volume and service organisations were well represented, approximately 20% each. Most of the participants were from management or advisory positions. Business size ranged from 10 to ~2500 employees, with more extreme outliers and an interquartile range from 120 to 2000.

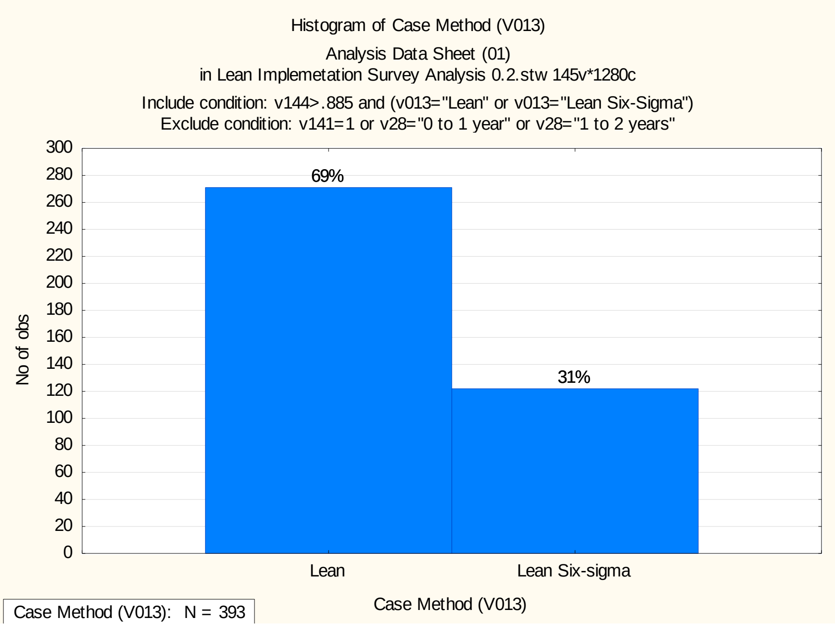


Figure 89 Distribution of the lean and lean six sigma cases (histogram).

[126] *For interpretation of the chart readers should note*, the *not at all* and *don't know* answers should in actuality have a higher response rates. Participants tend to skip questions, leaving blanks rather than answering with *not at all* or *don't know*. Indications are 100 to 200 points of missing data in the experience and implementation questions (V008 to V012). This was observed from the questions total counts. The *don't know* answers were counted as missing data and were removed from the analysis data set.

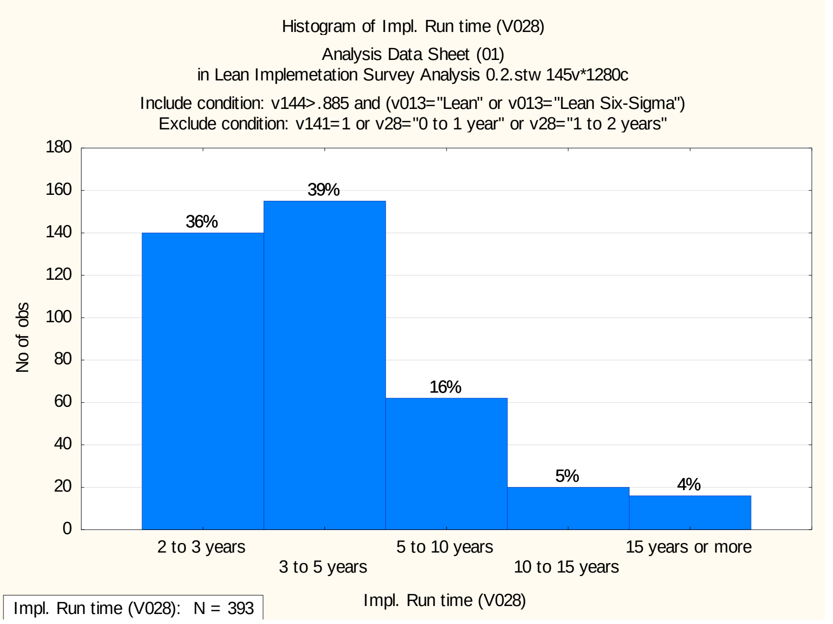


Figure 90 Lean and lean six sigma cases analysis: run time distribution (histogram)

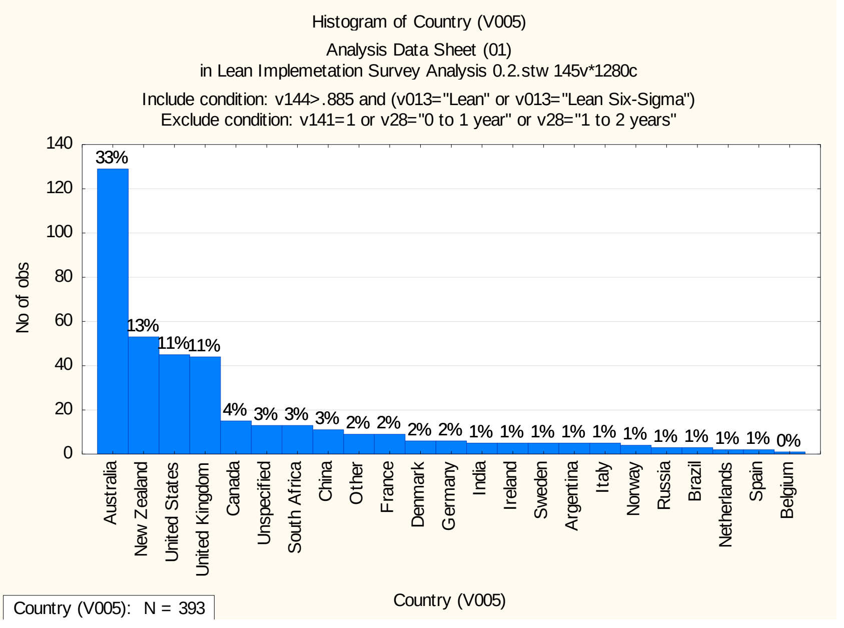


Figure 91 Lean and lean six sigma cases analysis: country Pareto chart.

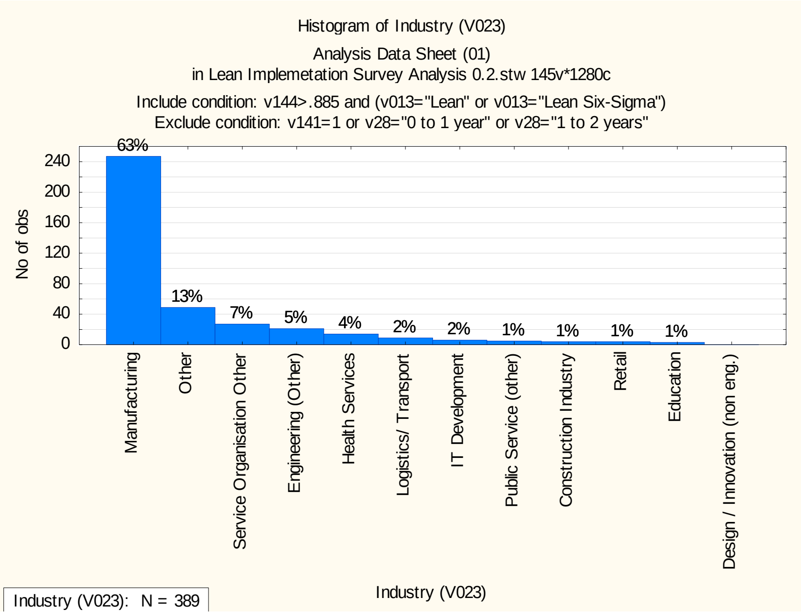


Figure 92 Lean and lean six sigma cases analysis: industry Pareto chart.

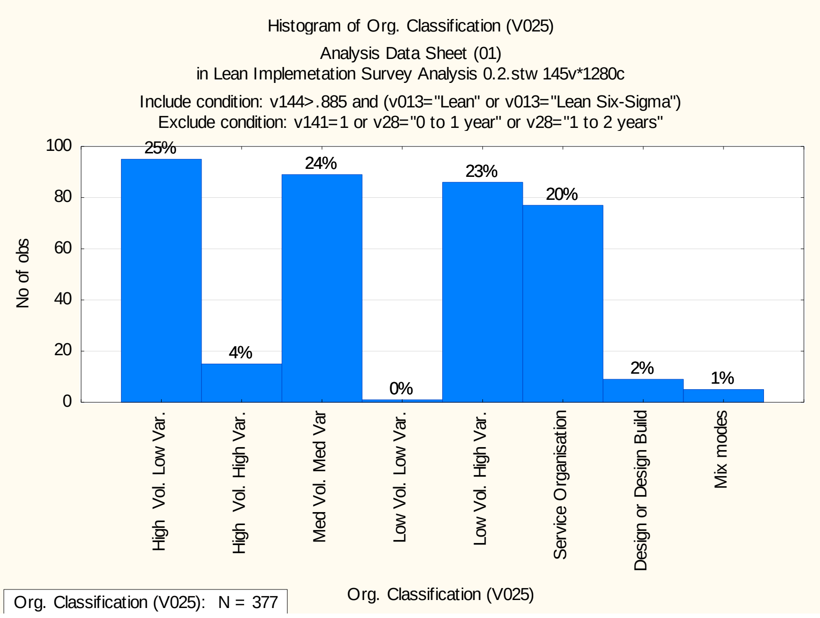


Figure 93 Lean and lean six sigma cases analysis: organisation classification chart.

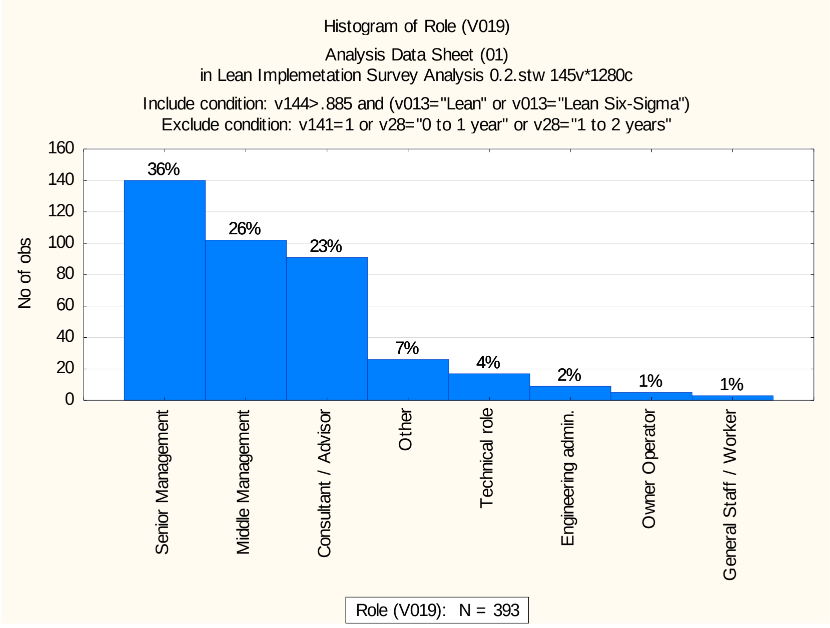


Figure 94 Lean and lean six sigma cases analysis: role of participant Pareto chart.

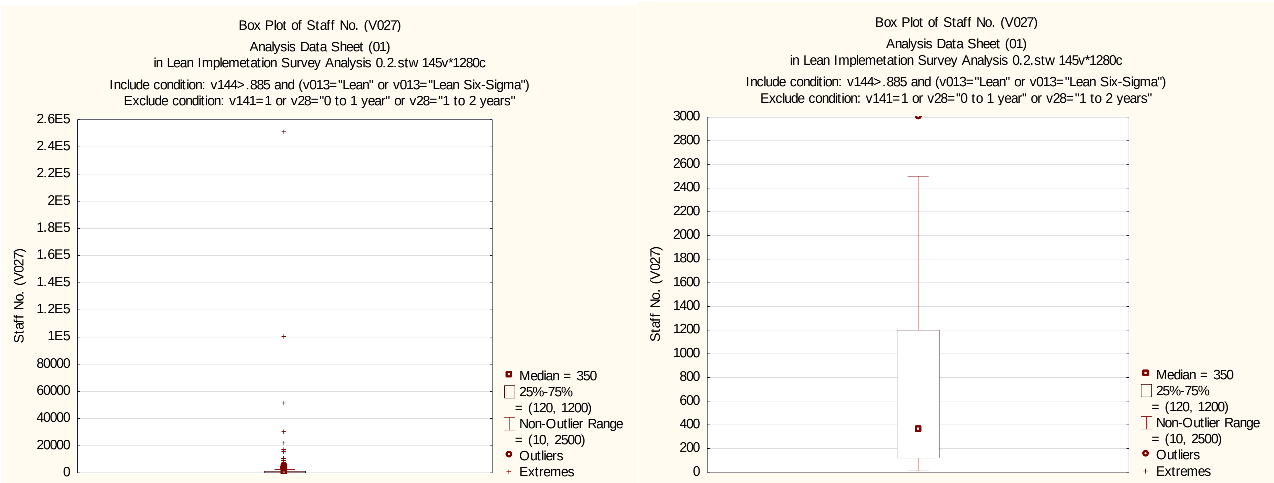


Figure 95 Lean and lean six sigma cases analysis: staff numbers (box plot)

7.4 Variable Ranking—Importance to Success

To identify key success factors, the variables were ranked for relative importance to success. The outputs of three methods were comparison to confirm rankings. The lists was then validated by predictive model building.

7.4.1 Verification by Three Methods

Pearson's correlation matrix (r) and two variable selection algorithms[127] were used for ranking variables for importance to Implementation Success (V162). The algorithms allow for linear and non-linear relationships (StatSoft, 2013a). Individually the tests do not provide strong validity. The algorithms are somewhat heuristic (StatSoft, 2013a, 2013b) and the suitability of using Pearson's r correlations to a binary categorical variable is questionable (Jacoby & Matell, 1971; Jamieson, 2004). The agreement between the multiple methods and testing by prediction is the strength of this approach (Y. (Jett) Lee, 2013).

Pair-wise deletion of missing data was used for initial iterations and case-wise deletion for final rankings. Pair-wise and case-wise deletion was compared for the ranking of 25 variables (Figure 96, left hand comparison). Some minor disagreement between rankings occurred. The pairwise method was deemed adequate for first iterations and interpretation, where the limitations are understood. Pairwise deletion ensures a larger data set for the calculation of each effect. It better represented the relative effect size over the full list. A full variable ranking list, by pair-wise deletion of missing values, is included in the appendix, Figure 279, page 440.

Algorithms by chi-square and F-statistic showed strong agreement. Of the 25 tested variables only one variable changed rank. There was an insignificant 0.1 discrepancy in one variables effect size (Figure 96, right hand side comparison).

The r-matrix showed general agreement with the algorithms but also had some significant differences. The comparison was made to an iterated algorithm ranking (see Figure 97, ref. Figure 98, and Figure 104). Differences greater than three ranking positions were considered significant. Four major differences in ranking were investigated. Pull Systems (V094) shifted 11 positions, Visual Systems (V098) moved 10 positions, Program/Structure/Regularity (V078) shifted 9 positions and Culture Initial priority (V049) moved 4 positions. These variables ranked lower in the r correlations, and is explained by the inability for Pearson's r to handle non-linear variables. These variables showed non-linear relationships with Success V162. See ranking table and means plots Figure 97, page 218.

[127] One algorithm was run taking Likert variables as continuous predictors and the other as categorical variables. The former compared by F-Statistic and later by Chi-Square.

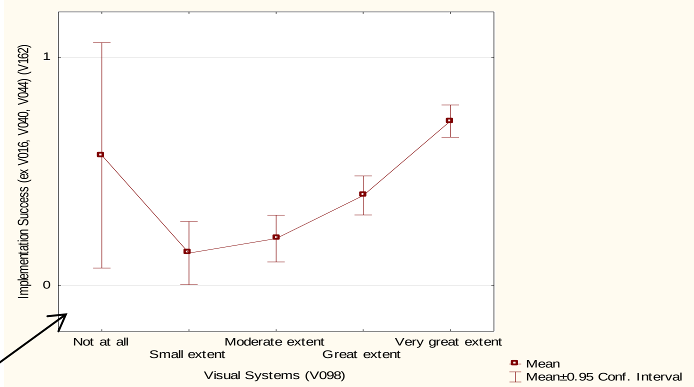
Rank	Algorithm, Chi square Variable	Pair-wsie Deletion Chi-square	p-value
1	Mgmt. contin. to learn and participate (V105)	87.2	0.000000
2	Staff had KPIs/ clear goals (V104)	78.8	0.000000
3	Worker Initiatives (V041)	76.0	0.000000
4	Mgmt. - Comm. Staff Role (Alignment) (V052)	75.2	0.000000
5	Visual Systems (V098)	72.5	0.000000
6	Management Commit. (V036)	71.2	0.000000
7	Involved all Staff (V057)	70.3	0.000000
8	Mgmt. - Effective Com. Process (V050)	70.0	0.000000
9	Growth mindset (can learn/ improve) (V075)	66.8	0.000000
10	Easy for suggestion/ improvements. (V048)	66.6	0.000000
11	Culture Initial priority (V049)	64.8	0.000000
12	Mgmt. - Vivid Comm. Strategy / Vis] (V051)	62.6	0.000000
13	Standard work developed (V080)	59.2	0.000000
14	Mgmt understood as a new culture/ philosophy (V068)	59.0	0.000000
15	Mgmt. - Vivid Com. Steps of Change (V053)	58.8	0.000000
16	Easy to maintain momentum (V070)	57.1	0.000000
17	Momentum Constant (V032)	54.9	0.000000
18	Mgmt understood tools/ methods (V067)	54.3	0.000000
19	Pull Systems (V094)	54.2	0.000000
20	Program/ Structure/ Regularity (V078)	53.7	0.000000
21	Staff Trusted Mgmt (V056)	52.6	0.000000
22	Mgmt. Planned Well (V047)	51.1	0.000000
23	Mgmt. had exclnt lean knwldge (V055)	50.1	0.000000
24	Mgmt established lean knowledge at start (V106)	50.0	0.000000
25	Management Capability (V064)	48.8	0.000000

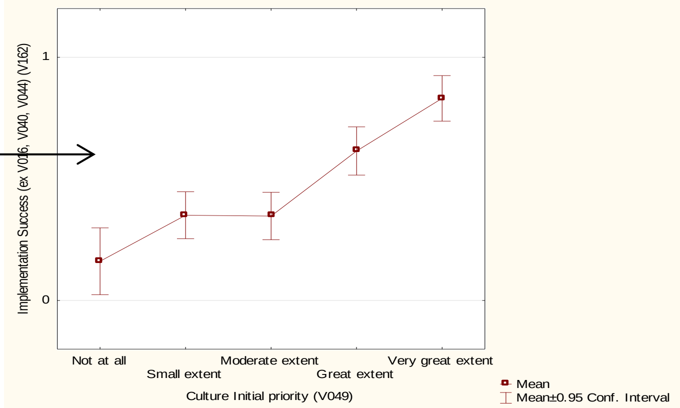
Rank	Algorithm, Chi square Variable	Case-wise Deletion Chi-square	p-value
1	Mgmt. contin. to learn and participate (V105)	87.2	0.000000
2	Staff had KPIs/ clear goals (V104)	77.5	0.000000
3	Worker Initiatives (V041)	73.6	0.000000
4	Mgmt. - Comm. Staff Role (Alignment) (V052)	73.5	0.000000
5	Visual Systems (V098)	73.0	0.000000
6	Involved all Staff (V057)	68.3	0.000000
7	Management Commit. (V036)	68.3	0.000000
8	Mgmt. - Effective Com. Process (V050)	67.9	0.000000
9	Culture Initial priority (V049)	67.8	0.000000
10	Growth mindset (can learn/ improve) (V075)	61.8	0.000000
11	Easy for suggestion/ improvements. (V048)	61.7	0.000000
12	Mgmt. - Vivid Comm. Strategy / Vis] (V051)	57.5	0.000000
13	Mgmt. - Vivid Com. Steps of Change (V053)	55.8	0.000000
14	Mgmt understood as a new culture/ philosophy (V068)	52.6	0.000000
15	Standard work developed (V080)	52.3	0.000000
16	Staff Trusted Mgmt (V056)	49.3	0.000000
17	Pull Systems (V094)	49.0	0.000000
18	Easy to maintain momentum (V070)	47.6	0.000000
19	Mgmt understood tools/ methods (V067)	46.0	0.000000
20	Mgmt. had exclnt lean knwldge (V055)	45.3	0.000000
21	Mgmt. Planned Well (V047)	44.2	0.000000
22	Program/ Structure/ Regularity (V078)	43.5	0.000000
23	Individual support in adjusting (V079)	41.2	0.000000
24	Momentum Constant (V032)	40.7	0.000000
25	Staff in Planning. (V039)	38.6	0.000000

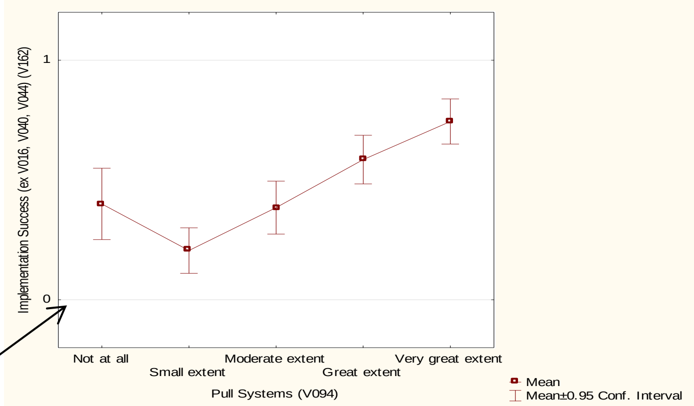
Rank	Algorithm, F-statistic Variable	Case-wise Deletion F-value	p-value
1	Mgmt. contin. to learn and participate (V105)	27.9	0.000000
2	Staff had KPIs/ clear goals (V104)	24.0	0.000000
3	Worker Initiatives (V041)	22.5	0.000000
4	Mgmt. - Comm. Staff Role (Alignment) (V052)	22.5	0.000000
5	Visual Systems (V098)	22.3	0.000000
6	Involved all Staff (V057)	20.7	0.000000
7	Management Commit. (V036)	20.5	0.000000
8	Culture Initial priority (V049)	20.5	0.000000
9	Mgmt. - Effective Com. Process (V050)	20.4	0.000000
10	Growth mindset (can learn/ improve) (V075)	18.4	0.000000
11	Easy for suggestion/ improvements. (V048)	18.4	0.000000
12	Mgmt. - Vivid Comm. Strategy / Vis] (V051)	16.9	0.000000
13	Mgmt. - Vivid Com. Steps of Change (V053)	16.3	0.000000
14	Mgmt understood as a new culture/ philosophy (V068)	15.2	0.000000
15	Standard work developed (V080)	15.1	0.000000
16	Staff Trusted Mgmt (V056)	14.2	0.000000
17	Pull Systems (V094)	14.1	0.000000
18	Easy to maintain momentum (V070)	13.6	0.000000
19	Mgmt understood tools/ methods (V067)	13.1	0.000000
20	Mgmt. had exclnt lean knwldge (V055)	12.8	0.000000
21	Mgmt. Planned Well (V047)	12.5	0.000000
22	Program/ Structure/ Regularity (V078)	12.3	0.000000
23	Individual support in adjusting (V079)	11.6	0.000000
24	Momentum Constant (V032)	11.4	0.000000
25	Staff in Planning. (V039)	10.7	0.000000

Figure 96 Comparing pairwise vs. case-wise deletion (F-value vs. Chi Square). This shows an early iteration of the top 25 variables.

Iterated Rank	Algorithm (chi-square) Iterated Top 20 List	Rank by r	Differ-ence
1	Mgmt. contin. to learn and participate (V105)	1	0
2	Staff had KPIs/ clear goals (V104)	3	1
3	Worker Initiatives (V041)	4	1
4	Mgmt. - Comm. Staff Role (Alignment) (V052)	2	-2
5	Visual Systems (V098)	15	10
6	Involved all Staff (V057)	5	-1
7	Culture Initial priority (V049)	11	4
8	Management Commit. (V036)	7	-1
9	Mgmt. - Effective Com. Process (V050)	6	-3
10	Growth mindset (can learn/ improve) (V075)	9	-1
11	Easy for suggestion/ improvements. (V048)	8	-3
12	Mgmt. - Vivid Comm. Strategy / Vis] (V051)	10	-2
13	Mgmt. - Vivid Com. Steps of Change (V053)	12	-1
14	Mgmt understood as a new culture/ philosophy (V068)	13	-1
15	Standard work developed (V080)	18	3
16	Easy to maintain momentum (V070)	14	-2
17	Pull Systems (V094)	28	11
18	Staff Trusted Mgmt (V056)	17	-1
19	Mgmt understood tools/ methods (V067)	16	-3
20	Program/ Structure/ Regularity (V078)	29	9







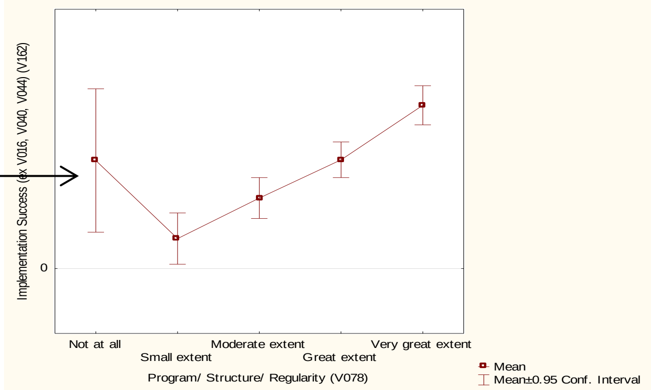


Figure 97 Agreement between algorithm and r correlation rankings. Highlighted variables move >3 positions. These variables exhibited a non-linear relationship with V162 Success (see plots).

Extracting Predictors of Implementation Success

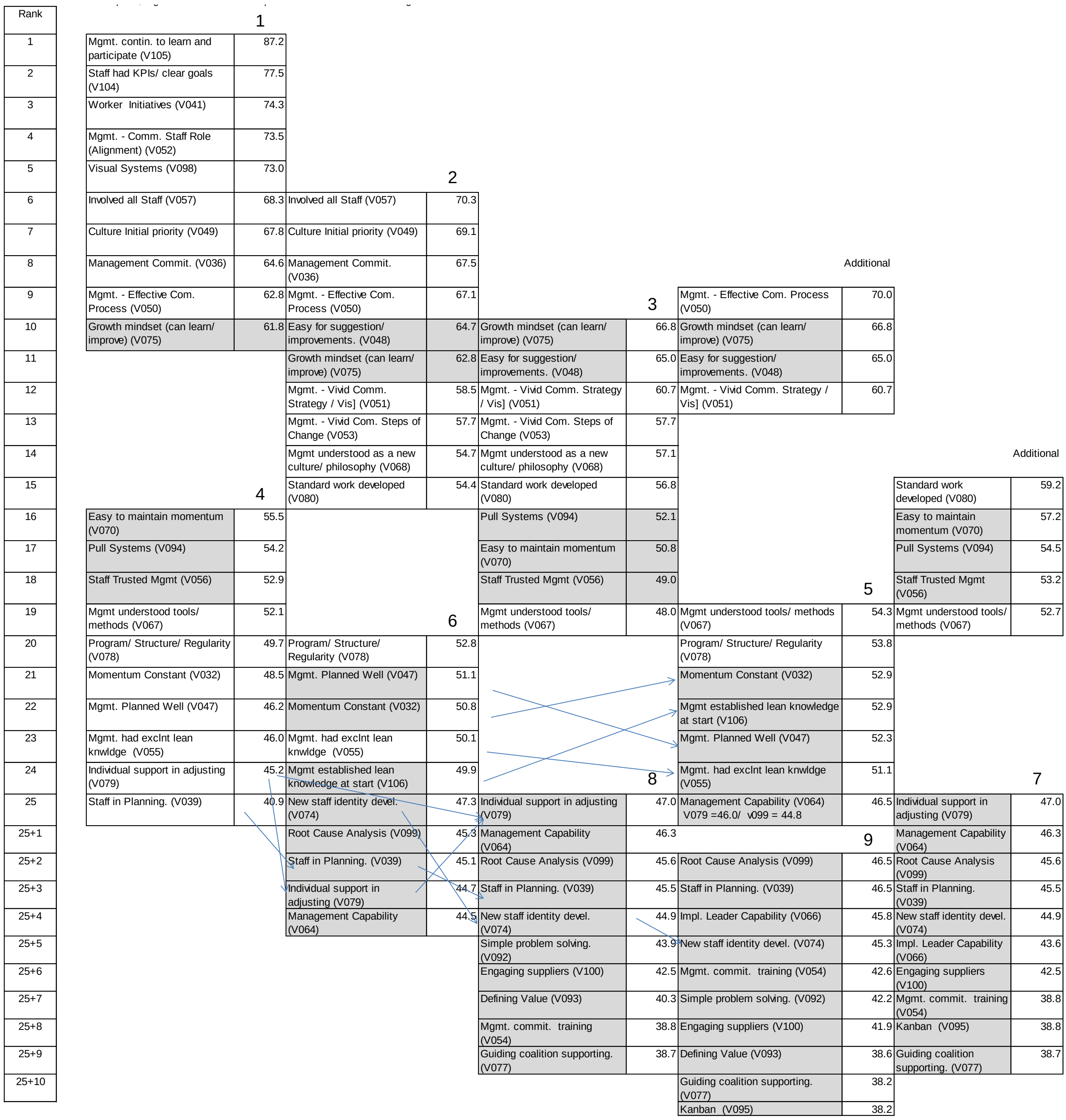


Figure 98 Extracting the top 25 predictors of Implementation Success (V162). Variables were extracted using a screening algorithm (Chi-square) on overlapping subsets of data as illustrated. Numbers 1 to 9 represented the subset analyses. Therefore effect size is relative to the subset. Highlighted variables needed the rank to be interpreted across multiple subsets.

In principle, all three methods agreed validating the approach. Because Pearson's r correlations were not robust to non-linear relationships, the algorithm approach was chosen. Chi square was the recommended approach for a categorical predictor.

To extract the top 25 predictors an iterative approach was used. The top 50 variables were selected from the full sample using pair-wise deletion of missing data. Using case-wise deletion, the top 25 variables were then ranked by iterations on overlapping variable subsets. Typically the subsets contained 10 variables. This produced more balanced results than full pairwise deletion. The resultant comparative is seen in Figure 98 (p. 219). The final ranking, Figure 104 is presented and discussed on page 223 after validation.

Validation by Prediction Model

The significance of top predictors was tested by building them into a prediction model. A simple CHAID Classification & Regression Tree (CHAID C&RT) was trained from a validation set. Random number allocation split the data ¾ training to ¼ for validation (test) Figure 99. The validation data set (24%) was used to test for over fitting of the C&RT model.

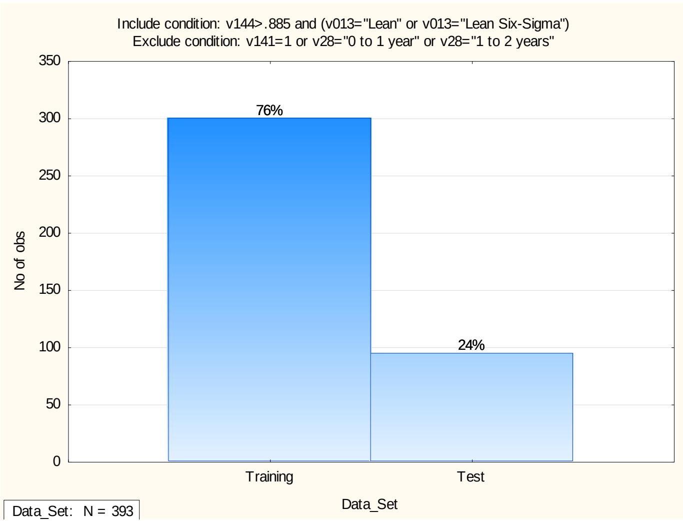


Figure 99 Lean and lean six sigma cases analysis: training and testing set distribution.

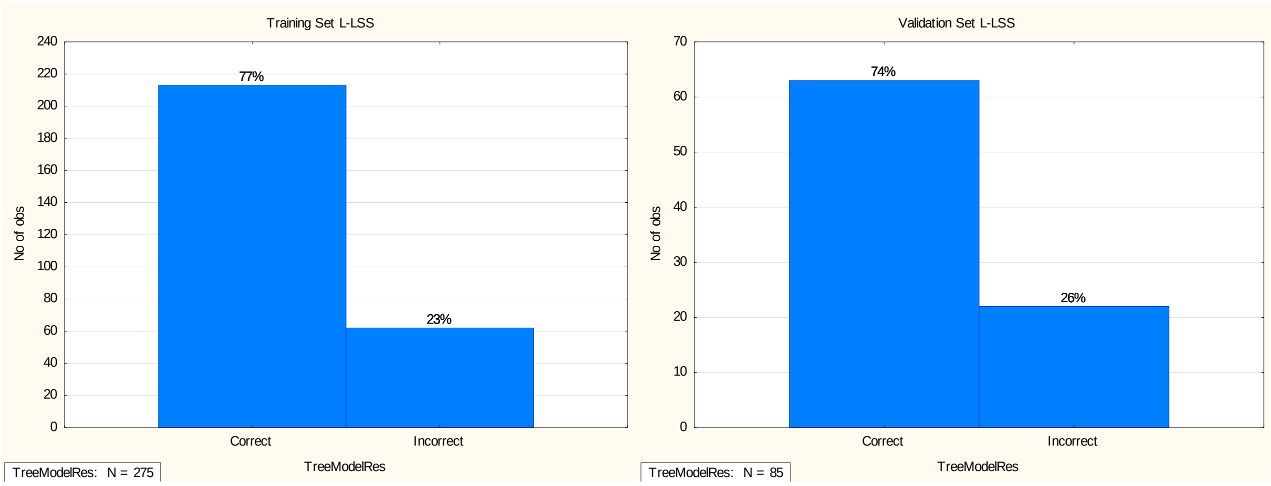


Figure 100 C&RT prediction accuracy: L-LSS training (LHS) and validation (RHS)

Statistica C&RT algorithm built the predicting trees. An initial C&RT (formed from the top 12 variable list[128]) was over fitted. It predicted a high 90% accuracy in training but only 67% in validation. The complexity of the model (nodes and variables) was reduced so comparable accuracy was achieved over

[128] Variables used: 105, 104, 41, 52, 98, 36, 57, 50, 75, and 48

training and validation data sets, 77% and 74% accurate respectively (Figure 100). The resultant model utilised the following variables: Management continued to learn and participate (V105), Visual Systems (V098), Easy for suggestion/improvements (V048), and Management Commitment (V036), Worker Initiatives (V041), Staff had KPIs/clear goals (V104), Management - Effective Communication Process (V050), and Involved all Staff (V057). A sufficient 73% accurate prediction was achieved across the full set. See below Figure 101 and Figure 102. By nature the regression does not include all significant predictors but general validation of the ranking method is achieved.

Poor predicting cases were analysed for common features (Figure 103). Few significant insights could be inferred. Typically, previous high predictors were repeated. Country (V005) featured with a very insignificant effect p=0.5. Defining Value (V093) featured highly.

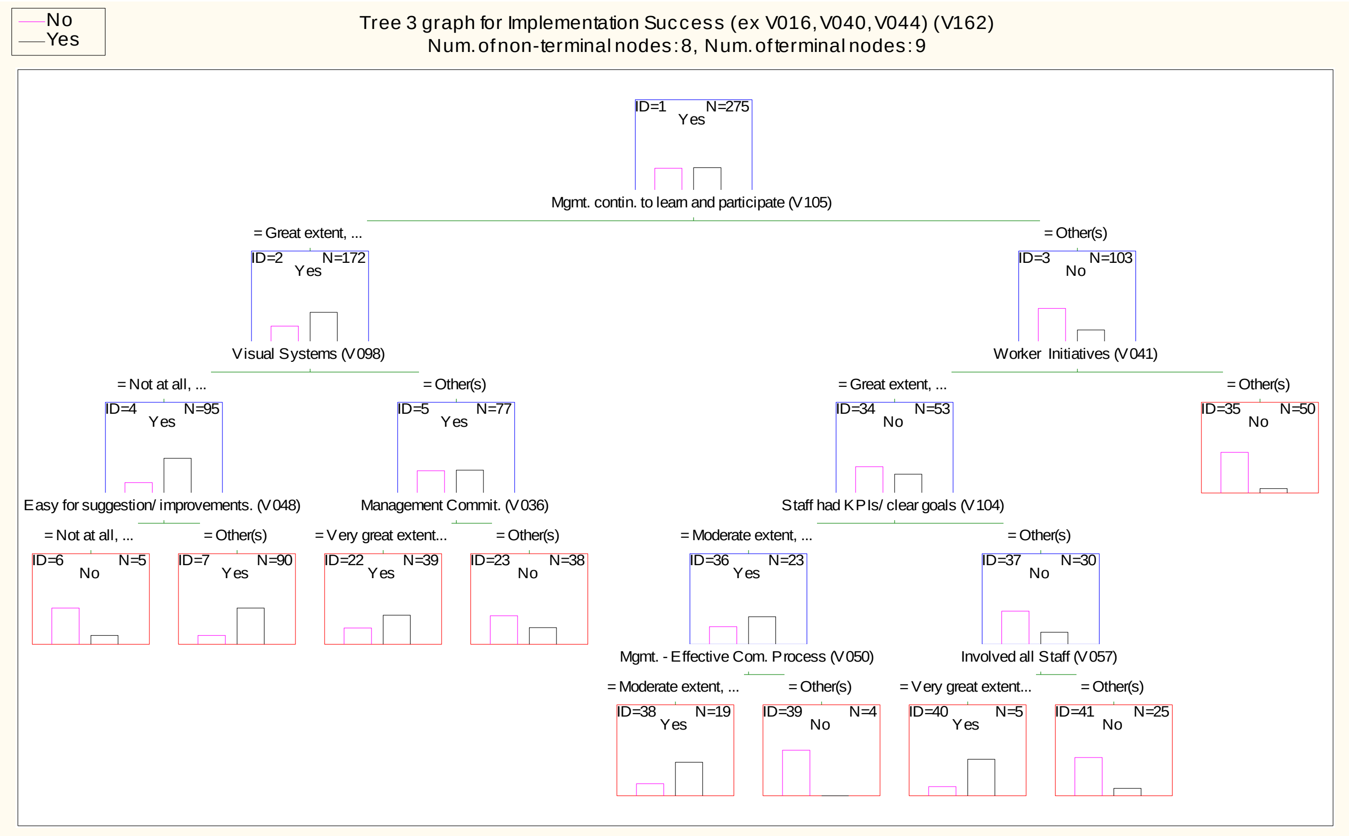


Figure 101 Simple CHAID classification & regression tree (CHAID C&RT) prediction model.

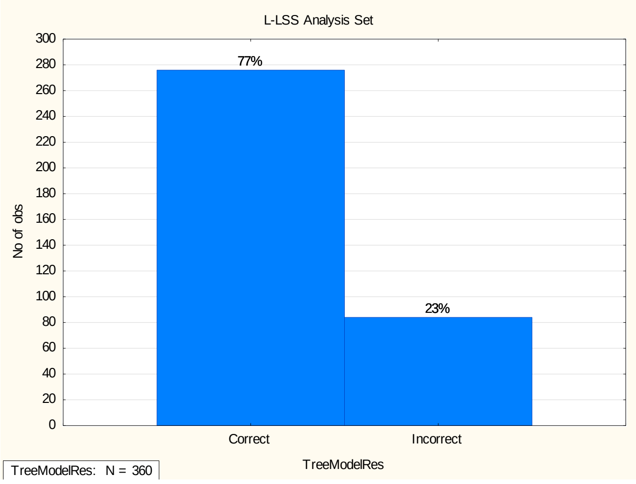


Figure 102 C&RT prediction accuracy for L-LSS full analysis set.

	Chi-square	p-value
Country (V005)	20.9	0.464
Visual Systems (V098)	17.4	0.002
Pull Systems (V094)	17.2	0.002
Culture Initial priority (V049)	16.8	0.002
Growth mindset (can learn/improve) (V075)	15.5	0.004
Management - Comm. Staff Role (Alignment) (V052)	15.4	0.004
Defining Value (V093)	15.3	0.004
Program/Structure/Regularity (V078)	13.6	0.009
Easy for suggestion/improvements (V048)	12.7	0.005
Staff in Planning(V039)	12.1	0.016
Standard work developed (V080)	12.1	0.017
Kanban (V095)	12.0	0.017
Staff had KPIs/clear goals (V104)	12.0	0.017
Management established lean knowledge at start (V106)	11.7	0.020
A3 Management, or Nemawashi or Catchball process (V088)	11.4	0.022
Management - Vivid Comm. Steps of Change (V053)	11.4	0.022
Management - Effective Comm. Process (V050)	11.2	0.025
Worker Initiatives (V041)	11.1	0.011
Individual support in adjusting (V079)	11.0	0.027
Total Productive Maintenance (V089)	10.5	0.033
Used Incentives (V042)	10.0	0.041
Involved all Staff (V057)	9.9	0.043
Kaizen (Kaikaku) Improvement Events (V090)	9.3	0.054
Simple problem solving (V092)	9.3	0.055
Management understood as a new culture/philosophy (V068)	9.3	0.055
Guiding coalition supporting (V077)	9.0	0.060
Lean/flow accounting (V058)	8.9	0.063
Staff Capability (V062)	8.4	0.038
Root Cause Analysis (V099)	8.3	0.080
Management - Vivid Comm. Strategy/Vis] (V051)	8.2	0.085

Figure 103 The significant effects on incorrect "Yes" predictions cases. Algorithms used pairwise deletion of missing data and the sample size range was 184 to 200.

7.4.2 Outcomes – Top Predictors

Top 25 Predictors of Implementation Success

The top 25 predictors of lean success are given in Figure 104. Variables ranked as 21-25 were common in that range but specific order was not well defined (see Figure 98). An illustration of relative effect size is given for the top 15 variables[129] in Figure 105.

1	Mgmt. contin. to learn and participate (V105)	14	Mgmt understood as a new culture/ philosophy (V068)
2	Staff had KPIs/ clear goals (V104)	15	Standard work developed (V080)
3	Worker Initiatives (V041)	16	Easy to maintain momentum (V070)
4	Mgmt. - Comm. Staff Role (Alignment) (V052)	17	Pull Systems (V094)
5	Visual Systems (V098)	18	Staff Trusted Mgmt (V056)
6	Involved all Staff (V057)	19	Mgmt understood tools/ methods (V067)
7	Culture Initial priority (V049)	20	Program/ Structure/ Regularity (V078)
8	Management Commit. (V036)	21 -25	Momentum Constant (V032)
9	Mgmt. - Effective Com. Process (V050)	21 -25	Mgmt. Planned Well (V047)
10	Growth mindset (can learn/ improve) (V075)	21 -25	Mgmt. had exclnt lean knwldge (V055)
11	Easy for suggestion/ improvements. (V048)	21 -25	Mgmt established lean knowledge at start (V106)
12	Mgmt. - Vivid Comm. Strategy / Vis] (V051)	21 -25	Individual support in adjusting (V079)
13	Mgmt. - Vivid Com. Steps of Change (V053)		

Figure 104 The top 25 predictors of implementation success (V162)

[129] At 15 variables ranking closely matched final ranking.

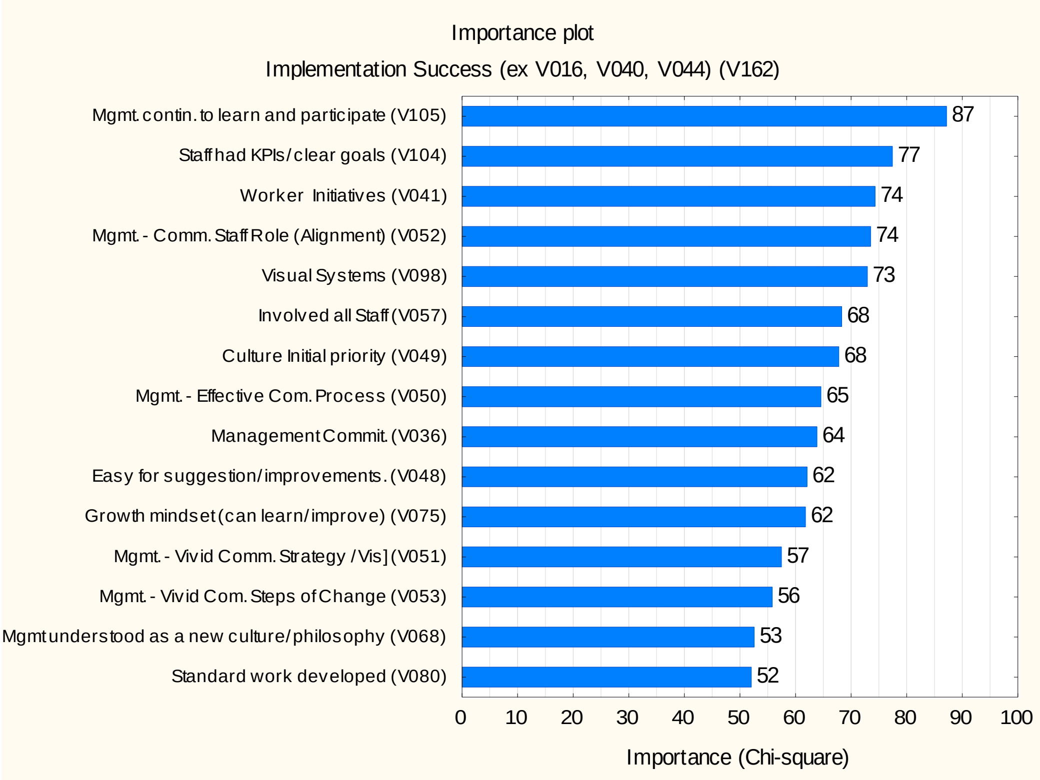


Figure 105 The top 15 predictors of implementation success (V162) – Pareto chart illustration of effect size (algorithm with chi-square, n=358 by case-wise deletion of missing data)

Top 5 Variables

The top 5 variables were strongly agreed on by all analytical approaches.[130] And the extent management continued to learn and participate in implementation (V105)[131] was the top predictor. Figure 105 shows a chi-square effect of 87 for V105, 10 higher than the next best predictor (chi-square=77 for V104).

The concept of V105 was highly related to management knowledge, as was Hypothesis 1:

> ***Hypothesis 1: The major success and failure factor for lean is leadership knowledge.***

V105 specifically emphasised the leader's attitude towards: continual development of knowledge (learning) combined with active participation in implementation. This is the continual development of the leader in the context of the implementation at hand. Experiential learning, the Gemba and positive interaction with employees are implied.

Management commitment was expressed as a key factor but it did not rank until number 8. Having excellent knowledge at the start of implementation (V055) featured in the top 25 but was not a top level predictor of success (ranked as 21-25, Figure 104). The attitude to learning and developing with the implementation is the most critical. This implies managers being happy to admit they don't know and are willing to try with

[130] Correlation matrix and algorithms: pair-wise and case-wise deletion, chi-square and F-statistic. Exception permitted for Visual Systems V098 by Pearson's r as non-linear relationship observed with Success V162.

[131] Q's: Did management continue to learn and participate throughout implementation?

active participation. This is a positive find for SMEs. An immediate outlay of resources and time is not necessary. Managers should be happy to develop a general understanding of holistic lean and progress further with their participation.

While V105 expresses the involvement and specific attitudes of the leader for success; additional highly ranked variables addressed the employees' involvement and the way they are led. Employees having clear measures of performance or goals communicated with them ranked second (V104). A related measure, the extent employees are informed how their roles align with strategy (V052) was ranked fourth. The encouragement, facilitation, and involvement of employee improvement initiatives were third (V041). The use of visual systems (V098) ranked fifth. This can be summarised:

> *For lean implementation success:* Management must be committed to lean, continuing to learn and participate in the implementation. Employees need to have clear goals, understand how their roles align with strategy, and be encouraged and enabled to carry out initiatives. Visual systems, is the key method, it should be used to support the implementation.

Top 25 Categorisation

The top predictors of success were placed in common logical categories or factors (Figure 106). These key factors were:

- The leader's attitude and knowledge
- Communication (with employee alignment)
- Enabling employee initiatives
- Momentum/regularity building culture
- Supporting employees with change
- Management planning
- Lean methods, tools and processes

These factors broadly cover leadership and enabling for organisational development, supported by lean methods, tools, and processes. This is in line with Hypothesis 2:

> ***Hypothesis 2: Consultants and the tools or methods of lean are secondary. The primary aspects are leadership and enabling development.***

It is noted that consultant variables did not feature at all in the top 25 factors, and only four of the 25 variables were related to the methods of lean. The categorised methods, tools, and processes are not complicated or even specific improvement techniques per se. Visual systems and standard work in principle are supportive of the desired behaviours, and an effective communication process is implemented by leadership to support change. Pull systems, a specific lean improvement techniques made the ranking list at 17th. Linking various processes in a pull system is a powerful step to reduce WIP and bring problems to the surface.

Leadership and Enabling for Organisational Developemnt

Leader Attitude and Knowledge	
1	Management contin. to learn and participate (V105)
8	Management Commit. (V036)
19	Management understood tools/ methods (V067)
21 -25	Management had exclnt lean knwldge (V055)
21 -25	Mgmt established lean knowledge at start (V106)

Communication (with Alignment)	
2	Staff had KPIs/ clear goals (V104)
4	Management - Comm. Staff Role (Alignment) (V052)
12	Management - Vivid Comm. Strategy / Vis] (V051)
13	Management - Vivid Comm. Steps of Change (V053)

Enabling Employee Initiatives	
3	Worker Initiatives (V041)
6	Involved all Staff (V057)
11	Easy for suggestion/ improvements. (V048)

Momentum/Regularity Building Culture	
7	Culture Initial priority (V049)
16	Easy to maintain momentum (V070)
20	Program/ Structure/ Regularity (V078)
21 -25	Momentum Constant (V032)

Employee Support in Change	
10	Growth mindset (can learn/ improve) (V075)
18	Staff Trusted Management (V056)
21 -25	Individual support in adjusting (V079)

Planning	
21 -25	Mgmt. Planned Well (V047)

Lean Methods, Tools and Processes

5	Visual Systems (V098)
9	Management - Effective Comm. Process (V050)
15	Standard work developed (V080)
17	Pull Systems (V094)

Comm. = communication

Cont. = continued

Figure 106 The categorised top 25 predictors of implementation Success (V162). The boxed number ranks variables according to importance

Business Size and Product Mix

	Chi-square	p-value
Management Commit. (V036)	27.8	0.0000
Engaging customers (V101)	27.3	0.0000
Involved all Staff (V057)	21.0	0.0003
Country (V005)	20.0	0.2188
Management continued to learn and participate (V105)	19.3	0.0007
Staff had KPIs/clear goals (V104)	18.1	0.0012
Easy to maintain momentum (V070)	17.8	0.0014
Momentum Constant (V032)	16.0	0.0031
Pull Systems (V094)	15.9	0.0031
Staff Trusted Management (V056)	15.5	0.0038
Individual support in adjusting (V079)	15.2	0.0044
Implementation Leader Capability (V066)	14.8	0.0020
Management established lean knowledge at start (V106)	14.7	0.0053
Kanban (V095)	13.7	0.0084
Worker Initiatives (V041)	13.6	0.0089
Easy for suggestion/improvements(V048)	13.0	0.0113
Management - Effective Comm. Process (V050)	12.6	0.0136
Standard work developed (V080)	12.1	0.0167
Program/Structure/Regularity (V078)	12.0	0.0177
Visual Systems (V098)	9.3	0.0535

In reviewing rankings, specific order is not critical if only a small change in effect is observed. This is particularly apparent in the lower ranked variables. For example, here V032 is 16.0, though only +3 on V048 at 13.0. It is ordered 8 places higher but the effect is not that different. By comparison v101 at 27.3 is 6.3 higher than the next variable V057 at 21.0.

Figure 107 The top 20 predictors of Success (V162) for small businesses (11 to 100 employees; n=69 by case-wise deletion of missing data).

Top predictors of Success V162 in small businesses were also investigated using the Statistica algorithm. An upper limit of 100 employees and lower limit of 11 employees was set. The top 30 predictors were selected using pair-wise deletion. Iterations of case-wise deletion were run on the top 30, then 20, 15 and 10. Comparing the top 20 with the top 15 and top 10, no difference in rank was observed. The top 20 predictors (Figure 107) were selected as a stable list. This analysis of small businesses had a reduced sample size (n=69 at 20 predictors). Many significant relationships ($p<0.05$) were still observed.

In the small businesses ranking (Figure 107) management commitment ranked highest, although commitment to learning and participating was still in the top 5. Many variables were repeated from the generic case but with slightly different ranking (cf. Figure 104). They still emphasised the same basic factors, leadership and enabling development with supportive tools.

Engaging customers did not feature in the generic case, but it was shown to be very important in small businesses, ranking an equivalent to first equal with management commitment.

- Small businesses may be inherently flexible, but limited resources can also impact their ability to handle variation. Customer behaviours can significantly affect lean systems (e.g. levelling of schedule). Additionally many small businesses may have few key clients of which the relationship is critical. Customers need to be engaged with the changes taking place and be brought to realise the ultimate benefits to them.

The implementation leader's capability also featured higher.

- Again, limited resources and specific vagaries impact small business and hence the need of high internal capability.

These two characteristics are identified for further investigation.

Also in the small businesses ranking, country featured in the top 20 ranking, but was very insignificant (p=0.2, p>>0.052).[132] The method, Kanban ranked higher than it had in the general case. This is logical as Kanban is the simple, practical application of pull systems. Visual systems ranked lower, but still made the top 20. Direct communication is easier in small businesses hence visual systems, although important may not be as critical as in larger businesses.

Comparison with businesses of 101 to 500 employees (Figure 108) shows an increased importance of Visual Systems. Leadership aspects including alignment and supporting staff in the change were still strongly influential, but the specific initiatives of staff were of less importance. Staff initiatives were on par with specific methods (e.g. defining value, problem solving, JIT). In large organisations the application of improvement by particular persons and teams is expected to be more critical. This could be a large number of employees but not all. This would be especially true for high-volume low-variety scenarios. This is apparent where product mix (Org. Classification[133] V025) also became a factor for success (Chi-square=17.9).

	Chi-square	p-value
Visual Systems (V098)	29.0	0.0000
Kanban (V095)	24.6	0.0001
Management understood tools/methods (V067)	22.7	0.0001
Staff had KPIs/clear goals (V104)	22.4	0.0002
Management - Vivid Communication of Strategy/Vision] (V051)	21.8	0.0002
Management continued to learn and participate (V105)	21.0	0.0003
Growth mindset (can learn/improve) (V075)	20.0	0.0005
Management - Effective Comm. Process (V050)	19.1	0.0008
Management Commit. (V036)	19.1	0.0003
Total Productive Maintenance (V089)	18.6*	0.0009
Org. Classification (V025) *	17.9	0.0065
Simple problem solving(V092)	17.6	0.0015
Just In Time Manufacture (V087)	17.0	0.0019
Management – Comm. Staff Role (Alignment) (V052)	16.4	0.0025
Individual support in adjusting (V079)	16.2	0.0028
Defining Value (V093)	15.9	0.0032
Worker Initiatives (V041)	15.5	0.0015
Pull Systems (V094)	14.7	0.0053
Staff Trusted Management (V056)	14.6	0.0056
Easy for suggestion/improvements(V048)	14.6	0.0057
**mainly differentiated by product mix		

Figure 108 The top 20 predictors of success (V162) for medium-large businesses (101 to 500 employees, n=118 by case-wise deletion of missing data).

[132] Histograms by country showed no significant insights.

[133] Organisation classification was primarily based on product variety and volume.

High-variation low-volume predictors stabilised at 13 variables; these had a significantly different ranking to small businesses (Figure 109 cf. Figure 107). The relationships observed for small business were unique, i.e. they are not a direct reflection of the general case or high representation of high-variety low-volume operations.[134] This was especially seen in the high ranking of engaging customers in the small business case.

	Chi-square	p-value
Worker Initiatives (V041)	28.6	0.0000
Involved all Staff (V057)	25.2	0.0000
Pull Systems (V094)	24.9	0.0001
Easy for suggestion/improvements(V048)	19.9	0.0005
Easy to maintain momentum (V070)	18.9	0.0008
Kanban (V095)	18.9	0.0008
Program/Structure/Regularity (V078)	17.7	0.0014
Implementation Leader Capability (V066)	16.5	0.0024
Staff Trusted Management (V056)	16.2	0.0010
Management continued to learn and participate (V105)	16.1	0.0028
Management - Vivid Comm. Steps of Change (V053)	15.9	0.0031
Management - Effective Comm. Process (V050)	15.2	0.0042
Standard work developed (V080)	13.4	0.0095

Figure 109 The top 13 predictors of success (V162) for high-variety low-volume producers, (n=73, case-wise deletion of missing data).

Figure 109 shows the importance ranking for high-variety low-volume classification; again, it is similar to the generic case yet with different emphasis. Worker initiatives and staff involvement were rated the highest.

- In a high product variety scenario, fine tuning of the value stream and process engineering has its limits.
- Worker initiatives and the involvement of all staff is more critical, enabling ongoing improvement, including fine tuning the way variation is handled by reducing set-up times.

Pull systems was third most important. Its application may be difficult in high-mix situations, but results indicate that there are large gains to be had with its appropriate application. Beyond these top three the ranking is somewhat arbitrary, and there are only small changes in the effect sizes. Besides some common leadership and enabling aspects, the methods were kanban systems and a strong communication process. Visual systems featured lower on the list, not making the top 13. Further analysis of the high-variety low-volume scenario is left for structural equation modelling. However, it is apparent that the main gains are coming from worker initiatives and not advanced processes.

7.5 Consultant Contribution

The consultant specific variable Consultant Capability (V065) needed specific analysis with reference to Consultants as a Coach. (V073), and Extent Implemented by Consultant (V035). The variable Consultant Use (V133) was used to select the cases where consultant were used.

[134] This possible biasing was further investigated in the SEM analysis, see Figure 132. It showed that a comparative number of samples were in each category.

The analysis of consultants contribution provided many interesting results. Figure 110 shows that only 21% of lean and lean six sigma cases did not use consultants. Correlation table Figure 111 shows that (in general) where consultants were used their capability, how much they coached and how much they actually were involved during implementation had no significant positive or negative bearing on the implementation. Figure 111 for comparison shows Management and Leader Capability were far more important than consultants (shown as p <<0.02 and r>>0.2), and even Technology featured as more important. One very weak (possibly insignificant) relationship was found for consultants; that is, that more management pressure (v061) was needed when consultants were involved in the implementation (v035). The effect was less than border line at r= 0.17 (B/L = 0.2) but had a significantly small p value of 0.01. Further investigation checked the influence (moderation) of consultant capability, see Figure 112.

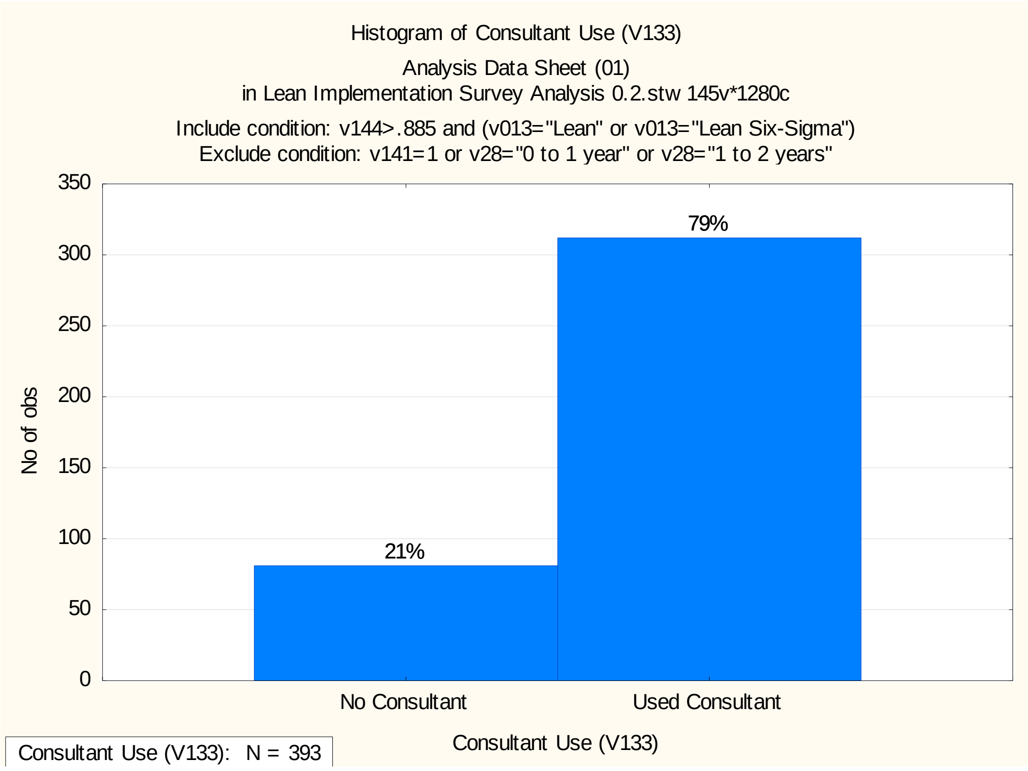


Figure 110 Consultant usage (V133) distribution: the cases where consultants were and were not used (lean and lean six sigma analysis).

	Impl. by consultants (V035)	Consultants as a coach. (V073)	Consultant Capability (V065)	Technology Capability (V063)	Management Capability (V064)	Impl. Leader Capability (V066)
Developed Self-improving Org. (V044)	.0157 p=.810	.0399 p=.542	.0280 p=.669	.2618 p=.000	.4165 p=.000	.3122 p=.000
Performance Enhanced (V016)	.0021 p=.975	.0663 p=.310	.0246 p=.707	.1835 p=.005	.3174 p=.000	.2923 p=.000
New Cult Developed (V038)	.0342 p=.601	.0788 p=.228	-.0126 p=.847	.2447 p=.000	.3999 p=.000	.2458 p=.000
Sustained Imp. (V040)	.0302 p=.644	.0644 p=.325	.0693 p=.289	.2563 p=.000	.4303 p=.000	.3519 p=.000
Mgt. Press still Needed (V061)	.1677 p=.010	.0743 p=.256	.0130 p=.843	-.1592 p=.014	-.2450 p=.000	-.2118 p=.001
New staff identity devel. (V074)	.1428 p=.028	.1241 p=.057	.1710 p=.008	.1856 p=.004	.2857 p=.000	.2723 p=.000
Employees resisted change (V102)	.0691 p=.291	.0527 p=.420	-.0349 p=.594	-.1007 p=.123	-.1902 p=.003	-.1847 p=.004

Marked correlations are significant at p < .05. N=236 (case-wise deletion of missing data for unbiased comparison with other variables). Include condition: v144>.885 and (v013="Lean" or v013="Lean Six-Sigma") and V133="Used Consultant"

Figure 111 Impact of consultant and capability variables of outputs correlation matrix (case wise deletion). No significant correlations for consultant variables were found, but significant correlations for other capability variables were.

	Consultant Capability Groups							
	All Capabilities		Masterful		Capable		Low / No ability	
	Impl. by consultants (V035)	Consultants as a coach. (V073)	Impl. by consultants (V035)	Consultants as a coach. (V073)	Impl. by consultants (V035)	Consultants as a coach. (V073)	Impl. by consultants (V035)	Consultants as a coach. (V073)
Developed Self-improving Org. (V044)	-.0355 N=308 p=.535	-.0059 N=305 p=.918	.2209 N=96 p=.031	.1822 N=96 p=.076	-.1054 N=116 p=.260	-.1141 N=117 p=.221	-.3658 N=54 p=.007	-.1289 N=53 p=.358
Performance Enhanced (V016)	-.0287 N=309 p=.616	.0408 N=305 p=.477	.1405 N=96 p=.172	.2365 N=96 p=.020	-.0744 N=117 p=.425	-.1165 N=117 p=.211	-.3263 N=54 p=.016	-.1124 N=53 p=.423
New Cult Developed (V038)	-.0115 N=307 p=.841	.0691 N=304 p=.230	.2300 N=95 p=.025	.2516 N=95 p=.014	-.1105 N=116 p=.238	-.0676 N=117 p=.469	-.3649 N=54 p=.007	.0123 N=53 p=.930
Sustained Imp. (V040)	-.0407 N=300 p=.483	.0183 N=297 p=.754	.1820 N=93 p=.081	.3224 N=93 p=.002	-.1015 N=114 p=.282	-.1813 N=115 p=.053	-.3342 N=53 p=.014	-.1461 N=52 p=.301
Mgt. Press still Needed (V061)	.1898 N=295 p=.001	.0689 N=292 p=.241	.1470 N=92 p=.162	.0313 N=92 p=.767	.2811 N=112 p=.003	.0749 N=113 p=.431	.3816 N=52 p=.005	.3081 N=51 p=.028
New staff identity devel. (V074)	.1235 N=304 p=.031	.1071 N=302 p=.063	.1359 N=96 p=.187	.0326 N=96 p=.752	.0995 N=114 p=.292	.0164 N=115 p=.862	-.0947 N=54 p=.496	.1870 N=53 p=.180
Employees resisted change (V102)	.1128 N=310 p=.047	.0911 N=307 p=.111	.0937 N=97 p=.361	-.0063 N=97 p=.951	.0673 N=117 p=.471	.1193 N=118 p=.198	.2650 N=54 p=.053	.2482 N=53 p=.073
Staff Morale Incr. (V017)	-.0233 N=308 p=.684	.0670 N=305 p=.243	.1492 N=97 p=.145	.1645 N=97 p=.107	-.1135 N=116 p=.225	.0125 N=117 p=.894	-.4314 N=54 p=.001	-.2265 N=53 p=.103

Marked correlations are significant at p < .05: Include condition: v144>.885 and (v013="Lean" or v013="Lean Six-Sigma") and V133="Used Consultant". Exclude condition: v141=1 or v28="0 to 1 year" or v28="1 to 2 years"

Figure 112 Impact of Consultants as a Coach. (V073), and Extent Implemented by Consultant (V035) on outputs. Multi-sampling matrix categorising by capability.

7.5.1 Masterful Consultants

The moderation effects of consultant capability were tested by multi-sampling. Where the capability of the consultants was *masterful* the consultant involvement still did not have strong correlations with the success outputs. Figure 112 shows some correlations of order r~0.2 and p~0.02. The correlations were on the positive side, towards lean success; but p is not that small (for data set size) and r is bottom limit significant, the correlations are very weak. Slightly stronger correlation were seen by Consultant as a coach (V073) than Implementation by consultants (V035). The most significant was Sustained Implementation (V040) by Consultant as a coach (V073) with r just above borderline at 0.32 but p highly significant (p<<0.02 at 0.002), see also plot in Figure 113. Consultant as a Coach (V073) also correlated moderately with Performance Enhanced (V016) and New Culture Development (V038). Developed Self-improving Organisations (V044) were not far off (r=0.18, p=0.076) but likely spurious. Other variables were management pressure, staff identity, and resistance to change; these showed no sign of correlation to Coaching or Implementation by Consultants. The weak correlations found were very much new culture related (V038) including developing a self-improving organisation (V044). Comparisons with resource capabilities show comparative significance (Figure 114). These consultant effects for masterful consultants were marginally stronger than Technology capability (V063) but still much weaker than capability of staff (V063), management (V064), and implementation leader (V066) across the same cases.

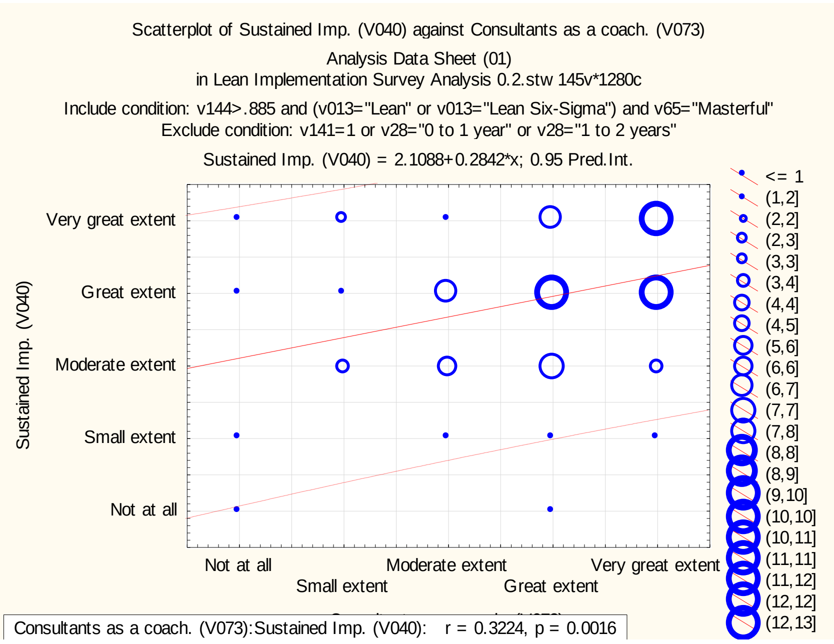


Figure 113 Sustained Implementation (V040) by Consultants as a Coach (V073) for masterful consultant capability.

7.5.2 Capable Consultants

The *capable* grouping found one significant effect but it was on the negative side (Figure 112). The increased involvement of a capable consultant in implementation correlated with an increased need for management pressure to maintain the initiatives (r=0.28, p=0.003) whereas consultant coaching did not (r=0.075, p=0.5). No other variables showed correlation.

7.5.3 Low and No Ability Consultants

Basic, Limited, and no capability consultants were grouped as *Low/No ability*; this allowed for adequate sample size and statistical power (Figure 112). This category showed the strongest relationships (6 instances $r_{absolute}$>0.3 and p<0.01) even though it had the smallest sample size (N<60 cf. N>90). All of the correlations found were negative to lean success. This Low/No ability sample group showed the extreme negative impact of the involvement of a poor consultant.

The consultant's involvement as a coach (V073) had less effect in the low/no ability category. A significant correlation was seen to management pressure being still needed (V06, r=0.38, p=0.03), and employees resisting the change (V102) was not far off (r=0.25, p=0.07). The staff morale indicator (V017) was added for this analysis. Figure 112 shows that staff morale found the greatest absolute correlation, r=-0.43, p=0.001. This negative correlation at low consultant capability was the only significant correlation from consultants to staff morale.

	Masterful Consultant Capability					
	Impl. by consultants (V035)	Consultants as a coach. (V073)	Staff Capability (V062)	Technology Capability (V063)	Management Capability (V064)	Impl. Leader Capability (V066)
Developed Self-improving Org. (V044)	.2209 N=96 p=.031	.1822 N=96 p=.076	.3617 N=97 p=.000	.1606 N=96 p=.118	.4066 N=97 p=.000	0.379 N=97 p=.000
Performance Enhanced (V016)	.1405 N=96 p=.172	.2365 N=96 p=.020	.2816 N=97 p=.005	.1557 N=96 p=.130	.2922 N=97 p=.004	0.277 N=97 p=.006
New Cult Developed (V038)	.2300 N=95 p=.025	.2516 N=95 p=.014	.3130 N=96 p=.002	.1289 N=95 p=.213	.4064 N=96 p=.000	0.266 N=96 p=.009
Sustained Imp. (V040)	.1820 N=93 p=.081	.3224 N=93 p=.002	.3428 N=94 p=.001	.2088 N=93 p=.045	.3989 N=94 p=.000	0.288 N=94 p=.005
Mgt. Press still Needed (V061)	.1470 N=92 p=.162	.0313 N=92 p=.767	.0636 N=93 p=.545	.0696 N=92 p=.510	-.1809 N=93 p=.083	-0.050 N=93 p=.636
New staff identity devel. (V074)	.1359 N=96 p=.187	.0326 N=96 p=.752	.3017 N=97 p=.003	.1966 N=96 p=.055	.2926 N=97 p=.004	0.405 N=97 p=.000
Employees resisted change (V102)	.0937 N=97 p=.361	-.0063 N=97 p=.951	.2517 N=98 p=.012	.1068 N=97 p=.298	-.0328 N=98 p=.749	-0.056 N=98 p=.587

Marked correlations are significant at p < .05: Include condition: v144>.885 and (v013="Lean" or v013="Lean Six-Sigma") and V133="Used Consultant". Exclude condition: v141=1 or v28="0 to 1 year" or v28="1 to 2 years"

Figure 114 Success outputs by Consultant as a Coach (V073), Extent Implemented by consultant (V035) and capability variables. Correlation matrix

filtered for masterful capability consultants. Effect sizes were similar to those observed in Figure 111.

There were many effects observed for consultants' involvement in implementation. The *variable management pressure is still needed (V040)* was a litmus test for sustained implementation. It showed the second strongest correlation in the matrix (r=0.38, p=0.05). The key success variable, Developed Self-improving Organisation (V044) was the third strongest (r=-0.37, p=0.007). Lower but still significant were sustained implementation (V040), New Culture Development (V038) and Performance Enhanced (V016). Under this category, there was no correlation seen with developing a new staff identity (r=-0.09, p=0.49) and borderline significant for employees resistance to change (r=0.27, p=0.05).

7.5.4 Capability Distribution

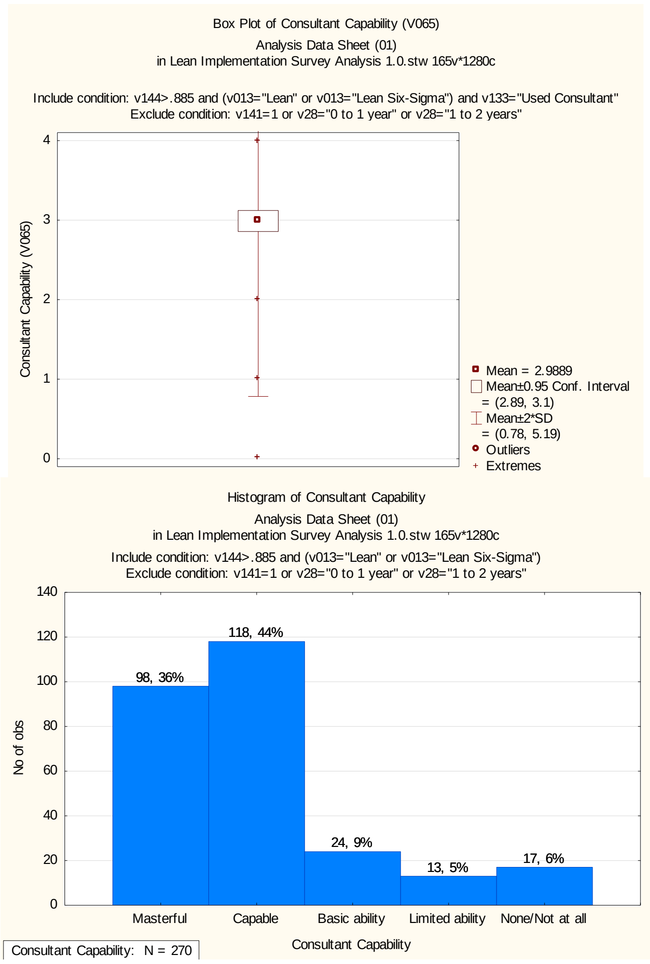


Figure 115 Means box plot and histogram for consultant capability. Box plot includes cases with consultants only (scale 0 through 4 is none/not at all, limited ability, basic ability, capable and masterful).

Figure 115 shows the distribution and means box plot for consultant capability. The average consultant Likert score was 3, that is capable (Figure 115). Over half of consultants, 64% were capable or less than capable, and only 36% were considered masterful.

7.5.5 Controls

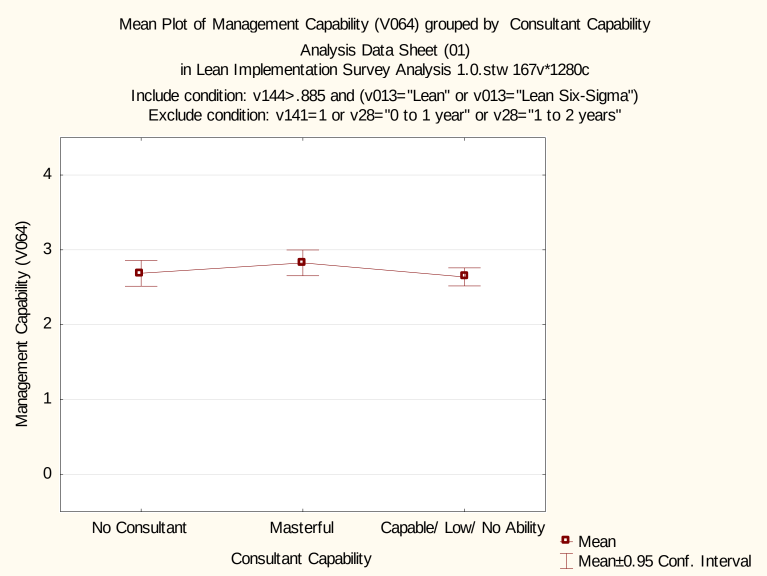


Figure 116 Means plot for Management Capability by Consultant Capability (scale 0- 4 is none/not at all, limited ability, basic ability, capable and masterful, Conf. interval= 95%)

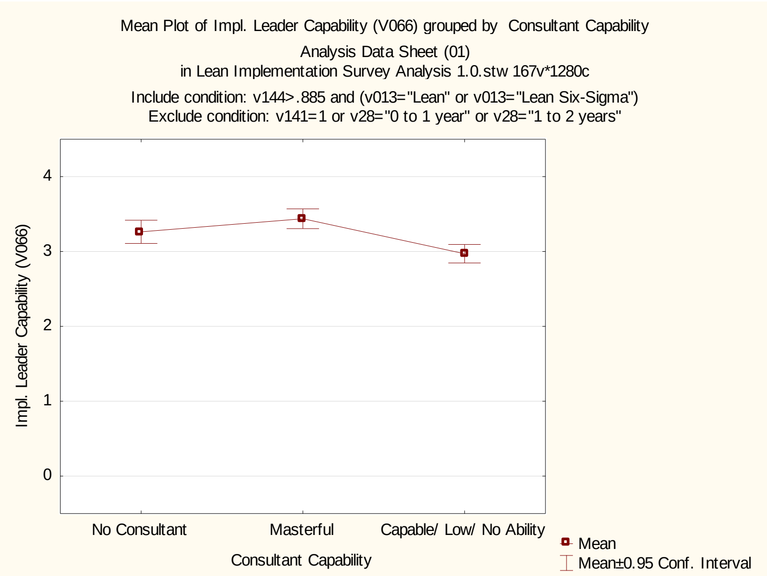


Figure 117 Means plot for Implementation Leader Capability by Consultant Capability (scale 0- 4 is none/not at all, limited ability, basic ability, capable and masterful, Conf. interval=95%)

The possibility of a spurious relationship driven by leadership excellence was investigated. Consultant absence could have been due to leadership excellence; therefore leadership excellence could have made the difference rather than the consultants presence. Means plots indicate that management and lean leader capability were comparable for both low capability and no consultant categories (Figure 116 and Figure 117). This indicates the similarity between consultant and no consultant cannot be explained by capability of management.

7.5.6 Outcomes – Consultant Contribution

The most significant contribution of consultants was negative. Significant negative correlations were observed with consultants of lower ability being involved in implementation. The negative correlations at low ability were significantly stronger (r and p) than the positive correlations for a masterful consultant.[135] Results were poor performance, in an unstained implementation, without the new culture developed, and no development of self-improving organisation. Both involvement in implementation and coaching correlated with the need for management to continually pressure the staff to maintain initiatives. There was indication of greater resistance among employees.

Masterful consultants had border line positive effects in specific areas. Involvement in implementation shows no direct correlation with performance enhancement but an indirect relationship (possibly mediation) through developing a self-improving organisation. Coaching does correlate weakly with performance enhancement, but slightly stronger with new culture development and sustained implementation.

This review of consultants confirms the importance of (1) an executive team making knowledge of lean internal (involving themselves in a learning process) and (2) from their knowledge gained selecting carefully any external support. Lean is not just getting in a smart person, graduate or statistician, to make processes more efficient. And the results have specifically addressed the type of support consultants should provide. The direct involvement of any consultant should be focused on coaching for sustainability. Any involvement of the consultant in carrying out the implementation, should be focused on the culture for lean, developing a self-improving organisation. The consultants key role is to coach for the sustaining of the implementation, developing of the right culture, and getting the performance enhancement desired. The drive for carrying out the implementation should be left with the internal leadership and employees. This is to develop the self-improving capability as opposed to having consultant driven improvements.

Only 36% of consultants were considered masterful. The remaining 64% were less than masterful. This indicates over half of the consultants practicing lean would have no positive impact on success but may have a high negative impact. This does not mean that a capable leadership team cannot select a good consultant that impacts change or performance positively. And it would be foolish to say there is not a place for specialist consulting and providing specialist skills. Even particular specialist technical skills could be provided as part of a much bigger picture. What is evident is that much care needs to be exercised in choosing consultants and having them fill the right functions. without conflict with the development of the organisation. Otherwise, a seemingly capable consultants can focus on performance enhancement through process improvements. This can readily neglect the people aspect, issuing in disengagement of employees and frustrating the development of the self-improving organisation.

[135] Even though sample size was smaller, n~ 50, vs. n~100.

7.6 Outcomes

This section contributed to the understanding of success factors i.e. the relative importance of key factors. The results were informative but inconclusive regarding the hypotheses.

> ***Hypothesis 2: Consultants and the tools or methods of lean are secondary. The primary aspects are leadership and enabling development.***

Supporting evidence was gathered for the consultant aspect of this hypothesis. Specifically, consultants were observed to have no significant effect on success, rather the majority of consultants were observed to impact outcomes negatively. Weak positive effects were seen for masterful consultants only. Other effects of lean consultants were marked for further investigation by SEM.

Ranking the top 25 predictors of success for the general case[136] supported Hypothesis 2. The aspects of leadership and enabling development dominated the list. These were:

- The leader's attitude and knowledge
- Communication (with employee alignment)
- Enabling employee initiatives
- Momentum/regularity building culture
- Supporting employees with change
- Management planning
- Lean methods, tools, and processes

The lean methods, tools, and processes that featured in the variable rankings were secondary and largely supportive of the change process. These were visual systems, standard work, and an effective communication process. One more process improvement orientated method, pull systems was also included.

Similar rankings were expected when controlling for business size and product mix to confirm Hypothesis 3:

> ***Hypothesis 3: The key success factors for lean do not differ due to business size, and product mix.***

This was not the case and **Hypothesis 3 was tentatively rejected.** In businesses of 11 to 100 employees, many of the common factors were present (although some rankings changed). However, engaging customers, which did not feature in the other lists, was ranked first, equal to management commitment. For mid-sized businesses Kanban and visual systems rated the highest, closely followed by leadership and enabling factors.

In effect, **Hypothesis 2 was accepted in general (across all cases) but was tentatively rejected in specific situations.** The statement of Hypothesis 2 can be modified and expanded:

> ***Statement 1 Leadership and enabling development are the primary factors for lean success. The key methods are visual systems, an effective communication process, and standard work. Particular techniques e.g. engaging customers, visual systems, and pull systems, are critical for specific situations. Consultants, unless masterful, do not help with long term performance and sustainability but could significantly hinder them. A masterful consultant can support positive outcomes through coaching.***

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[136] Not controlling for situational variables, e.g. business size, or product mix.

Hypothesis 1 addressed leadership knowledge:

> ***Hypothesis 1: The major success and failure factor for lean is leadership knowledge.***

The extent that management continued to learn and participate in an implementation (V105) was the top ranked variable. This relates to knowledge indirectly by showing an attitude of learning and willingness to participate. It relates directly to experiential knowledge, the knowledge of the developing implementation in the context of the business. In writing Hypothesis 1, a willingness to learn was presumed as a prerequisite knowledge. What was not expected was the very strong relationship between the attitude to seek knowledge and success. In posterior analysis this is logical as it expressed the commitment to learning. Other factors of management understanding did feature in the analysis however not enough to accept the hypothesis. Although this hypothesis could not be accepted, neither could it be rejected.

The primary factors and their relationship with management knowledge needed confirmation by SEMs.

8. Results from SEM

8.1 Context

The purpose of this chapter was to further the exploration of lean CSFs and finally address the hypotheses by structural equation modelling (SEM). Variable rankings had shown individual importance of factors but did not investigate underlying constructs, causality, mediation and moderation. Testing of latent constructs by PLS-SEM filled this gap. Ultimately, because of complex interactions, complex models were developed in order to understand the inner relationships.

8.1.1 Unresolved Hypotheses

To recap and bridge any gap from the previous qualitative chapters, it is helpful to discuss what was resolved and what still needed to be addressed.

> ***Hypothesis 4: New Zealand's senior managers (represented largely by those in SMEs) have been slow to pick up lean management.***

Hypothesis 4 was addressed in experiment One (p. 168). New Zealand manufacturing participants were shown to have low lean knowledge as opposed to USA participants. A degree of participant self-deception was also apparent from the data (p. 168). This did not require further analysis in this work.

Hypothesis 1 through Hypothesis 3 required further analysis.

> ***Hypothesis 1: The major success and failure factor for lean is leadership knowledge.***

This (Hypothesis 1) embodies the principal question for this work. Regarding resources and the resource-based view (Barney, 1991), knowledge is viewed as the preeminent resource of the firm (Grant, 1996). Hence deliberate learning (Zollo & Winter, 2002).The proposition here was that leadership lean knowledge is the primary resource for lean implementation. This is a knowledge-based view for lean.

Variable rankings could not convincingly resolve (accept or reject) the overriding effect of management knowledge on success. Secondary effects, mediation and moderation, needed investigation.

> ***Hypothesis 2: Consultants and the tools or methods of lean are secondary. The primary aspects are leadership and enabling development.***

> ***Hypothesis 3: The key success factors for lean do not differ due to business size, and product mix.***

Hypothesis 2 was accepted for the generic case but *tentatively rejected* in specific situations. Hypothesis 3 was tentatively rejected. Hypothesis 2 and Hypothesis 3 were recast in Statement 1.

> ***Statement 1 Leadership and enabling development are the primary factors for lean success. The key methods are visual systems, an effective communication process, and standard work. Particular techniques e.g. engaging customers, visual systems, and pull systems, are critical for specific situations. Consultants, unless masterful, do not help with long term performance and***

sustainability but could significantly hinder them. A masterful consultant can support positive outcomes through coaching.

This statement needed further validation of causal relationships.

8.1.2 Data Characteristics and SEM Quality

Data characteristics and descriptive statistics were reviewed in the previous chapter. SEM quality validation was presented in detail in Chapter 6 and the literature is not repeated here. Refer to the quality analysis starting on page 182 as a worked example.

8.2 Exploration of a Lean Knowledge-Based View

8.2.1 SEM A—Simplistic Model

The exploration of a knowledge-based view for lean began with a small, simplistic model of resource capabilities. The premise of research Hypothesis 1 was that the capabilities are developed through leadership knowledge. The first SEM, SEM A investigates this; it introduces the lean knowledge-based view. This model was developed to show that although lean developed internal capabilities, other specific factors highly impact outcomes. Although the general capabilities were expected to play a part, previous work had indicated there was much more to lean than developing and utilising these. Two hypotheses summarised this:

H A.1: Resource capabilities, as influenced by leadership lean knowledge, are a partial mediator to outcome success.

H A.2: These established capabilities only describe a small portion of implementation outcomes and the influence of lean knowledge (that is other significant factors are at play).

Simplistic Model Construct Indicators

Three constructs were developed for the model: Management Knowledge,[137] Resources, and Outcomes. Management Knowledge and Outcomes have been discussed in detail throughout this work. These constructs were measured as shown in Figure 118. The Resources construct was covered by four key categories: management, technology, employee, and leadership capability. Although not encompassing all resources (Barney, 1991), this reflective measure was considered an adequate representation of internal capabilities. Specifically, process capability was not included; this would have skewed the construct from resource development towards lean process improvement.

[137] In this work, to separate SEM constructs from the general text, they are denoted in title case, with capitalisation of the first letter of each word e.g. Management Knowledge.

Management Knowledge	Resources
V055 Management had excellent lean knowledge V067 Management understood the tools/methods V068 Management understood as a new culture/philosophy V105 Management continued to learn and participate V106 Management established lean knowledge at the start	V062 Staff Capability V063 Technology Capability V064 Management Capability V066 Implementation Leader Capability
Outcomes	
V015 Competitive Advantage V016 Performance Enhanced V017 Staff Morale Increases V038 New Cult Developed[138] V040 Sustained Imp. V044 Developed Self-improving Org.	

Figure 118 Lean Knowledge-Based View construct indicators (set 1)

Indicator Loadings			
	Mgmt. Know-ledge	Outcomes	Resources
V015 Competitive Advantage		0.80	
V016 Performance Enhanced		0.82	
V017 Staff Morale Incr.		0.69	
V038 New Cult Developed		0.84	
V040 Sustained Imp.		0.80	
V044 Developed Self-improving Org.		0.84	
V062 Staff Capability			0.74
V063 Technology Capability			0.68
V064 Management Capability			0.85
V066 Impl. Leader Capability			0.64
V055 Mgmt. had exclnt lean knwldge	0.73		
V067 Mgmt. understood tools/ methods	0.82		
V068 Mgmt. understood as a new culture/ p	0.81		
V105 Mgmt. contin. to learn and participate	0.79		
V106 Mgmt established lean knowledge at	0.71		
Basic criterion for loading is >0.7. Lower loadings are accepted in exploratory work and removal of slightly lower loadings in PLS SEM is discouraged to support consistency at large.			

Figure 119 SEM A.2 indicator loadings.

Sufficiently strong indicator loadings (Figure 119) and reliability was achieved for all latent constructs according to general guidelines.[139] All paths were significant to p<0.001 (bootstrapping 5000 times). Internal

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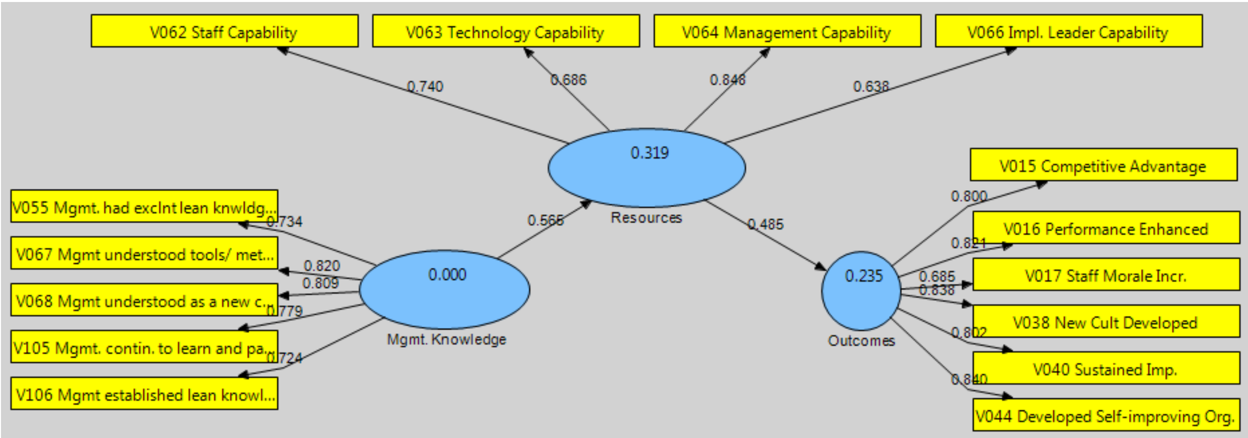
[138] Indicator V038 was used in SEM A but later removed in validation of larger models SEM B

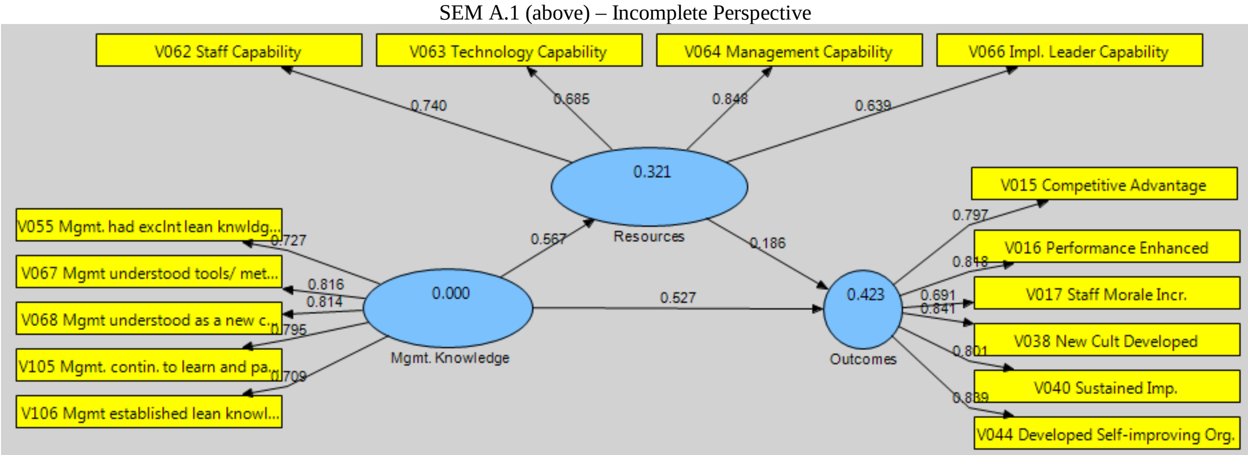
[139] Further exploration showed the indicator loadings and reliability recorded here, although meeting the general guidelines for explorative modelling, was not adequate for further analysis of causality. It did however serve the general purposes of this exploration.

and external model validity was assured, including a goodness of fit of 0.47 (Gof>0.31 recommended, see full quality validation p.461).

Hypothesis Testing



SEM A.1 (above) – Incomplete Perspective



SEM A.2– Complete Perspective i.e. lean knowledge has further influence.

Figure 120 SEM A: resource-based view for lean. Control analysis showing that resource development describes only a small amount of the outcomes. All paths are significant, p<0.001. For quality validation see p. 461.

The resultant models (Figure 102) strongly confirmed the hypotheses. SEM A.1 shows the direct effects of resources on outcomes. Path coefficients were strong (β=0.57 and β=0.49) and explain a significant but relatively small amount of the variance in outcomes (R^2=0.24). SEM A.2, adds a direct path between management knowledge and outcomes. The same strong relationships between leadership's lean knowledge and resource capability (β=0.57) were observed. Also a significant 32% (R^2=0.32) of the variance in resource capability was also explained (SEM A.1). The resources to outcomes path becomes weak, β=0.19. It was clear that management knowledge has a more significant effect. Management knowledge to resources had a strong path (β=0.53). In SEM A.2, nearly double the variance in Outcomes was explained. R^2 of 0.42 would be considered high for this exploratory work with only two exogenous constructs acting.[140]

[140] As earlier stated: *R^2 results are typically categorised as substantial, moderate, and weak. One scale is 0.67, 0.33, and 0.19 (Chin, 1998b; Henseler et al., 2009) and a similar alternative is 0.75, 0.50, and 0.25 (market research Joe F. Hair et al., 2011). Moderate values are deemed acceptable if only a few latent variables are exogenous. If several latent variables are acting substantial values are suggested (Henseler et al., 2009). This criterion is dependent on context, e.g.*

The hypotheses were accepted:

Accept H1.1: Resource capabilities, as influenced by lean knowledge, are a partial mediator to outcome success.

Accept H1.2: These established capabilities only describe a small portion of implementation outcomes and the influence of lean knowledge (that is other significant factors are at play).

While resource capabilities were related to the success of lean implementation, lean knowledge describes much more variance in outcomes. The direct path to outcomes was much stronger from management knowledge (β=0.53 cf. β=0.19).

- It was believed alternative partial mediators would sufficiently describe outcomes (to a substantial level[140]) through the indirect influence of lean knowledge.

These mediators had been foreshadowed by the variable importance rankings.

8.2.2 Sub Hypotheses: Lean Knowledge-Based View

Further models were used to advance the Lean Knowledge-Based View. This was needed for a comprehensive validation of the Hypotheses. Although the variable rankings indicated lean knowledge was influential, many other factors featured for successful implementation. These factors included the major components of Hypothesis 1 and 2[141] and were:

- The leader's attitude and knowledge
- Communication (with employee alignment)
- Enabling employee initiatives
- Momentum/regularity building culture
- Supporting employees with change
- Management planning
- Lean methods, tools and processes

These were the constructs been tentatively identified[142] as the major factors for successful implementation (outcomes).

The following sub hypotheses were formed:

H B.1 Outcomes of lean are substantially explained by communication (employee alignment); enabling employee initiatives; having momentum/regularity and building culture; supporting

in consumer behaviour 0.2 is considered high (Joe F. Hair et al., 2011). That said, a minimum of 0.1 is a reasonable guideline (Camison & Villar-López, 2012; ref. Falk & Miller, 1992).

[141] Includes all components except for the consultant.

[142] Through contextualization studies, variable rankings, and the body of knowledge.

employees with change; management planning, the extended value stream (engaging customers and suppliers) and the methods of lean.[143]

H B.2 Strong relationships exist between management knowledge and the success factors: communication (employee alignment); enabling employee initiatives; having momentum/regularity and building culture; supporting employees with change; management planning, the extended value stream (engaging customers and suppliers) and the methods of lean.[144]

H B.3 As per Hypothesis 2*:* The tools or methods of lean are secondary. The primary aspects are leadership and enabling development

HB.4 The aspects of change leadership and employee enablement are the key success factors independent of business size and product mix. Whereas, key methods will be situationally specific to business size and product mix. Some methods (e.g. visual systems and simple problem solving) are supportive of employee enablement benefiting all scenarios.

HB.5 In high variation low volume manufacture the enabling aspects will be particularly important, describing the majority of the benefits from lean.

HB.6 In small business (10-100 employees) and in high-variety low-volume production the simple methods will correlate with successful outcomes and more advanced process improvement (e.g. JIT) will not.

HB.7 In larger business (101-500 employees) and low-variety high-volume manufacture the advanced process methods will correlate with outcomes more significantly.

These hypotheses formed the base for the development of the SEM constructs and hypothesis models.

8.2.3 SEM B Intermediate Exploration (Constructs and Model)

An intermediate SEM exploration grouped similar indicators into common constructs. For example, significant lean methods were included in two logical constructs,[145] simple methods and advanced methods. These intermediate and explorative constructs are shown in Figure 121. These were coupled with the previous constructs from SEM A, Figure 118; the Resources construct had described a significant amount of variance in outcomes and so was included. The extended values stream had been identified as important in specific situations (Figure 107, p. 227). And so a construct for this was included. V093 Defining Value and V097 Mapping Value Stream were not included in this construct. Although they are relevant to the extended

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[143] The first two hypotheses reflect the outcomes from the variable rankings and attempt to validate the constructs chosen.

[144] Finding HB.1 and HB.2 true implicates lean knowledge as the overriding success factor.

[145] This logical division was made knowing analysis of reliability and factor loadings would validate the approach. See quality validation for developed models.

value stream and would have increased indicator numbers, they also could have biased theconstruct towards internal value stream improvements. These indicators were included in later, more developed models.

Enabling Employee Initiatives	**Momentum/Regularity**	**Extended value stream**
V039 Staff in Planning. V041 Worker Initiatives V048 Easy for suggestions/improvements. V057 Involved all Staff	V078 Program/Structure/Regularity V072 Small wins prominent V032 Momentum Constant V049 Culture Initial priority[146]	V101 Engaging customers V100 Engaging suppliers
Simple Methods	**Advanced Methods**	
V080 Standard work developed V091 5 Whys V098Visual Systems V092 Simple problem solving. V099 Root Cause Analysis	V089 Total Productive Maintenance V095 Kanban V094 Pull Systems V087 Just In Time Manufacture	

Figure 121 Lean Knowledge-Based View construct indicators (set 2—intermediate exploration).

Based on the developed constructs Figure 118 and Figure 121), the hypotheses were built into a simple exploratory SEM, Figure 122.

[146] Indicator V049 was removed in validation.

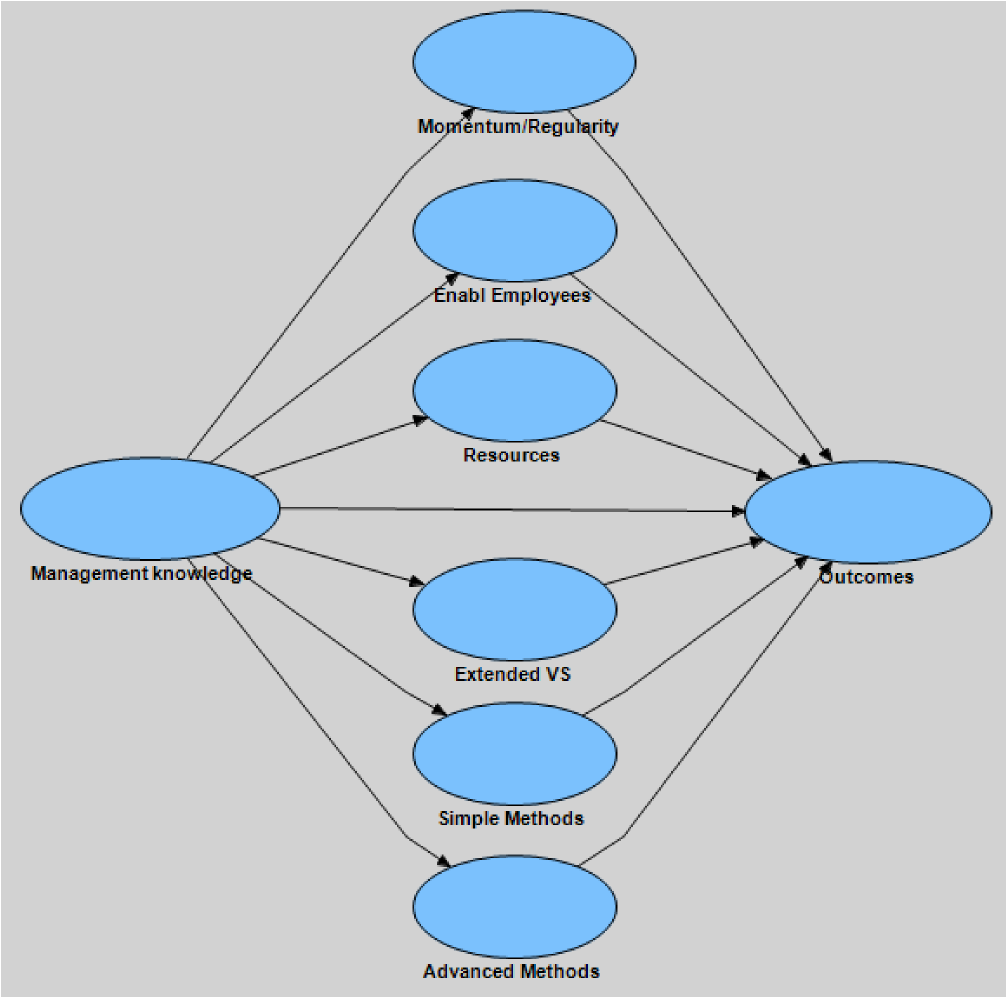

Figure 122 SEM for intermediate exploration of management knowledge as the root cause for success: the Lean Knowledge-Based View

Intermediate Exploration Outcomes

The intermediate exploration was informative but not conclusive. Key components of this analysis is included in the appendix, page 475. The problem with SEM B, was that the constructs did not provide enough resolution to uncover causality. The following specific issues were identified.

- Specific factors were expected to correlate highly but did not.[147]
- Outcomes construct was overrepresented by cultural aspects.

Lower indicator loadings and construct reliability are generally accepted in explorative analyse. However, this was shown to be inappropriate for unveiling causality and biased results.

> The adjusted approach was to develop smaller constructs of higher indicator loading (typically 0.8 or greater) which in turn produced higher construct reliability.

This meant the developed constructs had only a small number of indicators and many single indicator constructs were used.

[147] Specifically noticeable was that the advanced process construct, which included JIT, did not correlate highly with outcomes in the low-variety high-volume production analysis.

An additional insights was that V049 *Culture as an initial priority* cross loaded heavily. This caused problems with discriminant validity in many models. Having culture as an initial priority is highly significant, and it statistically confounded the analyses. Additionally, this variable represents an objective of leadership more than a specific action taken. Because of these two reasons, V049 was removed from further analysis.

8.2.4 Developed Constructs for the Lean Knowledge-Based View

Refined constructs were developed for use in further analyse (Figure 123). These were established based on the available variables, variable rankings, and categorisation (e.g. Figure 106, p. 226). The goal of the model was to uncover the main paths of causality for successful outcomes. To have confidence that the most significant mediation effects were included whilst minimising spurious effects, a large number of constructs was required.

Constructs	**Indicators (measured variables)**	**Constructs**	**Indicators (measured variables)**
5S	5S V086 5S System used	**Outcomes**	OC V016 Performance Enhanced
Communication	COM V050 Management developed an effective communication process		OC V040 Sustained Imp.
	COM V051 Management vividly communicated strategy/vision		OC V015 Competitive Advantage
	COM V052 Management communicated staff role	**Planning**	PL V047 Management planned well
	COM V053 Management vividly communicated the steps of change	**Problem Solving (Simple)**	PR V091 5 Whys PR V092 Simple problem solving
Employee Initiatives (Enabled)	EE V041 Worker Initiatives		
	EE V048 Easy for suggestion/improvements	**Pull/Kanban**	PUL V094 Pull Systems PUL V095 Kanban
	EE V057 Involved all Staff		REG V072 Small wins prominent
Engage Customers	ENC V101 Engaging customers	**Regularity**	REG V078 Program/Structure/Regularity
Engage Suppliers	ENS V100 Engaging suppliers	**Resource**	RES V062 Staff Capability
Guiding Coalition	GC V077 Guiding coalition supporting		RES V063 Technology Capability
Information Systems	ITS V085 Information Systems	**Statistical Methods**	STA V096 Statistical Methods
JIT	JIT V087 Just In Time Manufacture	**Standard Work**	STW V080 Standard work developed
Journey View	JV V031 Journey View	**Support Employees**	SU V075 Growth mindset
Kaizen Events	KAI V090 Kaizen		SU V079 Individual support in adjusting
Lean/Flow Accounting	LAC V058 Lean/flow accounting	**TPM**	TPM V089 Total Productive Maintenance
Management Knowledge	MK V067 Management understood tools/methods	**Value Flow**	V093 Defining Value V097 Mapping Value Stream
	MK V068 Management understood as a new culture/philosophy		
	MK V105 Management continued to learn and participate	**Visual Systems**	VS V098 Visual Systems

Figure 123 The Lean Knowledge-Based View revised constructs.

Specific notes regarding these constructs are:

- Indicators were selected through iterative trials for increased testing for reliability.
- Engaging customers and engaging suppliers were trialled in the same construct but loaded unevenly (dependent on data set).
- Kaizen Events and Statistical Methods were of particular relevance to current industry practice so included.
- Resources indicators were reduced to Staff Capability and Technology Capability to remove the leadership aspect. The construct weakly represented resources but was sufficient for this exploration.
- Outcomes were reduced to two performance indicators Performance Enhanced and Competitive Advantage, along with Sustained Implementation. Staff Morale, New Culture Developed and Developed Self Improving Organisation were removed to reduce the focus on cultural aspects. Developed Self Improving Organisation also cross loaded heavily and was removed.
- Management Knowledge was reduced to V067 Management understood the tools/methods, V068 Management understood lean as a new culture/philosophy and V105 Management continued to learn and participate. V055 (Management had excellent lean knowledge) and V106 (Management established lean knowledge at the start) were removed to increase the constructs indicator loading/reliability.
- Management Knowledge included “Continued to learn and participate” which expresses the attitude and willingness to gain the experiential and contextual knowledge of the business – associated with being at the gemba.

The below variables ranked in importance lists but were removed from the SEM analysis.

- *V104 Staff had KPIs/clear goals* is related to both the *support*, and *communication* (alignment) constructs. V104 loaded to the low standard (0.7) in the communication construct. It loaded well in the support construct (0.8-0.9) but this was dependant on which indicators it was paired with and which data set was used. Although a significant part of employee support and communication of their role V104 was not be included in the constructs.
- *V056 Staff Trusted Management* was not included in the analysis. This represents an attitude and outcome more than specific action taken.
- *V066 Implementation Leader Capability* ranked highly in the small business category. Again this does not represent a specific action and could be spurious, representing management capability further work could address.

Other notable exclusions were:

- Single minute exchange of dies (SMED) and specific quality tools and techniques (e.g. quality at the source) were not expressed directly in the analysis. These were covered in part by simple problem solving and employee initiatives but further studies could consider these among other factors.

Validation of these chosen constructs was later seen; they substantial described lean implementation outcomes (R^2 of Outcomes).

8.2.5 Investigation of Indicator V105

Within the Management Knowledge construct, the influence of indicator *V105 Management continued to learn and participate*, was investigated. Weaker effects of Management Knowledge on Outcomes were observed where V105 was removed from the construct. A trail SEM replace V105 with *V055 Management had excellent lean knowledge* and *V106 Management established lean knowledge from the start* (Figure 124 cf. Figure 125). These alternative Management Knowledge indicators (Figure 124) showed equivalent impact on outcomes as the commitment model i.e. R^2=0.25 (Figure 125) compared to R^2=0.27 (Figure 126). It was clear that *V105 Management continued to learn and participate* has significant effect on the strength of the Management Knowledge construct in explaining outcomes. Gaining the experiential knowledge of lean in the context of the business, is a key component of the required leadership for success. Indicator V105 loaded highly (and reliably) in the Management Knowledge construct (Figure 124) and was retained in the construct for further SEM analyses.

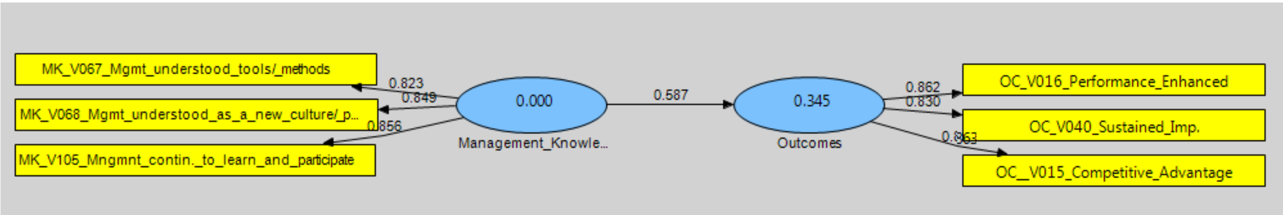

Figure 124 Management Knowledge effect on Outcomes (exploration of indicators chosen). Same indicators used as SEM K analysis.

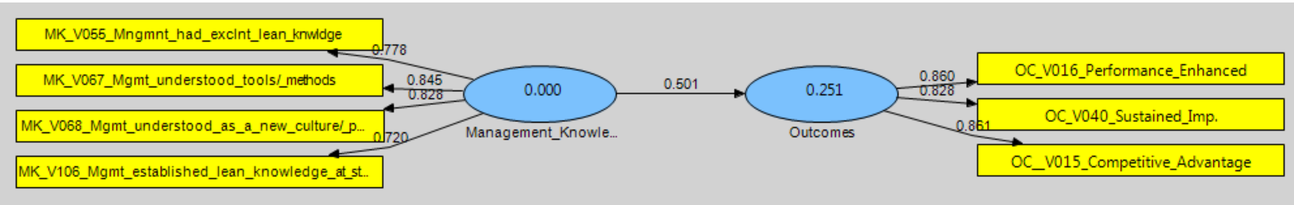

Figure 125 Management Knowledge effect on Outcomes (exploration of indicators chosen). *V105 Management continued to learn and participate* replaced with *V055 Management had excellent lean knowledge* and *V106 Management established lean knowledge from the start.*

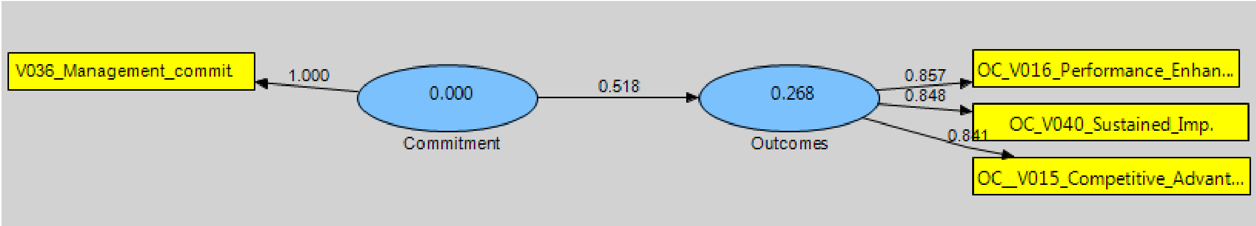

Figure 126 Management Commitment effect on Outcomes (exploration of indicators chosen).

8.2.6 Developing a Model for the Lean Knowledge-Based View (SEM K)

From the key lean constructs (Figure 121, p. 245) the hypothesis model (Figure 130) was developed to test the sub hypotheses (p. 243). The resultant model was complex due to many constructs and possible lines of causality. The following figures show the construction of the hypothesis model.

First, lean system components and internal resource constructs are shown in Figure 127. These show resources and the high process related concepts of lean in one cluster, and simple problem solving and basic methods (e.g. TPM, 5S) in a second cluster. Logical relationships between all the constructs were tested as other paths were eliminated.

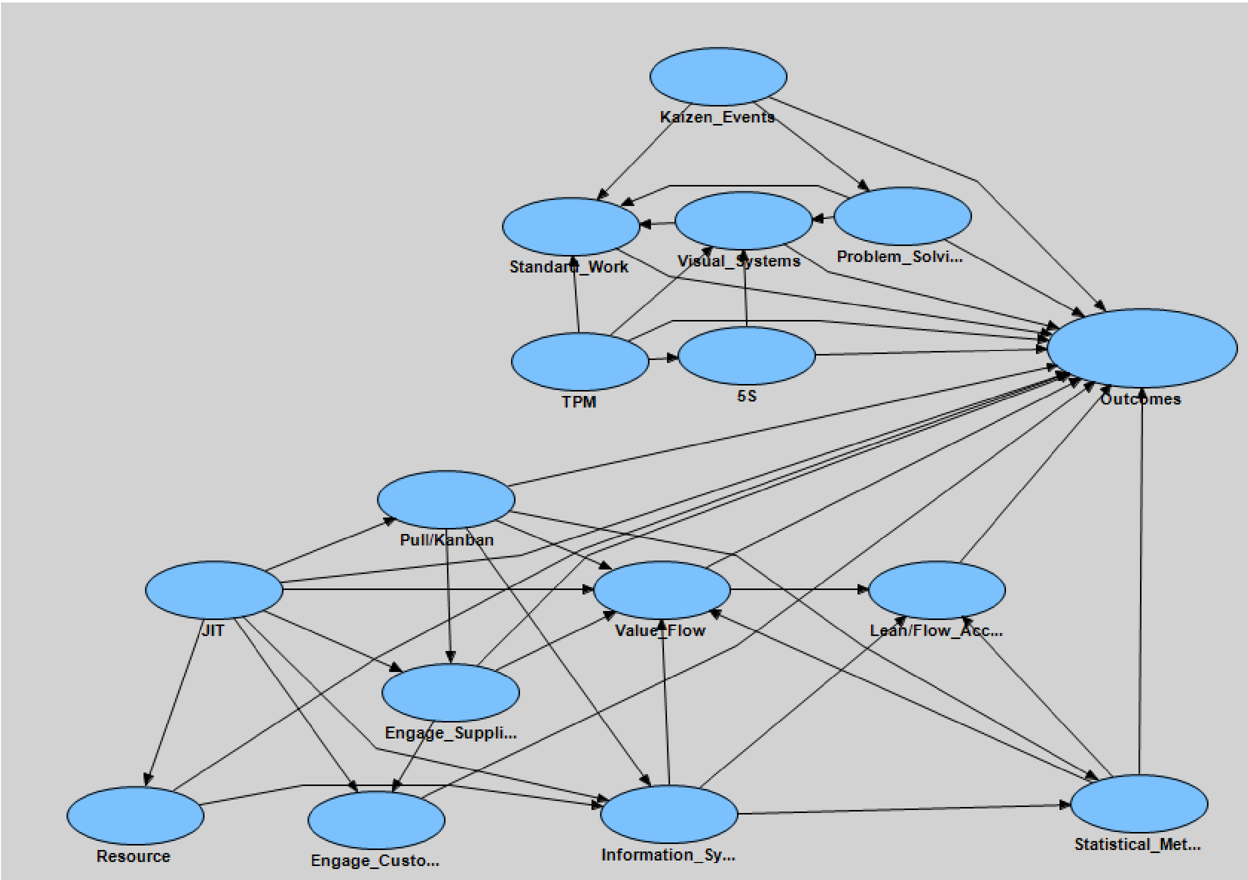

Figure 127 Lean components and internal resources describe outcomes in the hypothesis SEM.

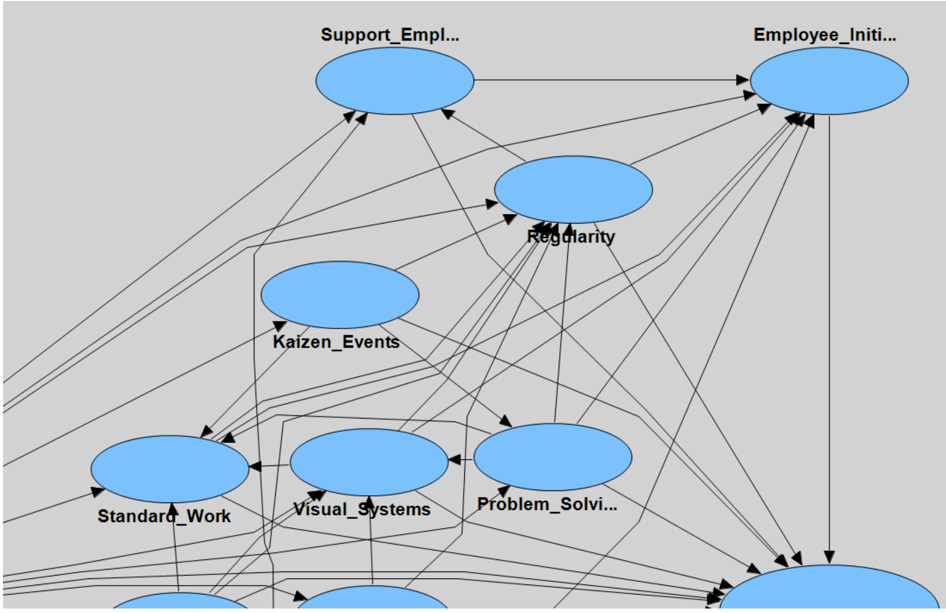

Figure 128 Adding enabling employee initiatives, support for employees, and regularity to the hypothesis SEM.

Second, employee initiatives, support for employees and regularity were added to the model, Figure 128.

- It was hypothesised that the methods of lean would describe outcomes moderately but effects would be highly moderated through leadership and enabling employees.

The momentum of change as represented by Regularity (program, structure, regularity and small wins) was believed to be a significant mediator although not directly effecting outcomes.

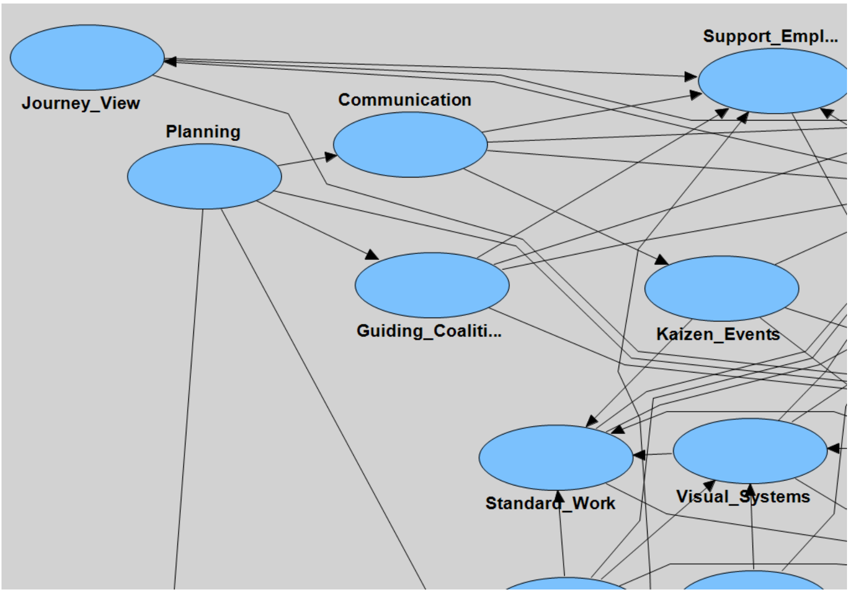

Figure 129 The higher strategic level of organisational development: adding planning, communication, forming a guiding coalition, and having a journey view to the hypothesis SEM.

Third, at a higher and strategic level of organisational development is having the journey view, planning, forming a guiding coalition, and developing an effective communication (including the process and alignment of staff). These were represented in Figure 129.

Planning and regularity were believed to serve related, but distinguishable functions. Regularity supports general success providing momentum, whilst planning is needed to lead specific changes. On one hand, the day to day desired behaviours can be maintained and built upon by some regular activity. This is not forcing change but maintaining it with the help of programme or structure, achieving progress through regular small wins. Alternatively, planning supports specific components of the lean system that require a planned step change. Activities such as adequately communicating the change with employees require forethought through planning. These concepts are represented in the path analysis.

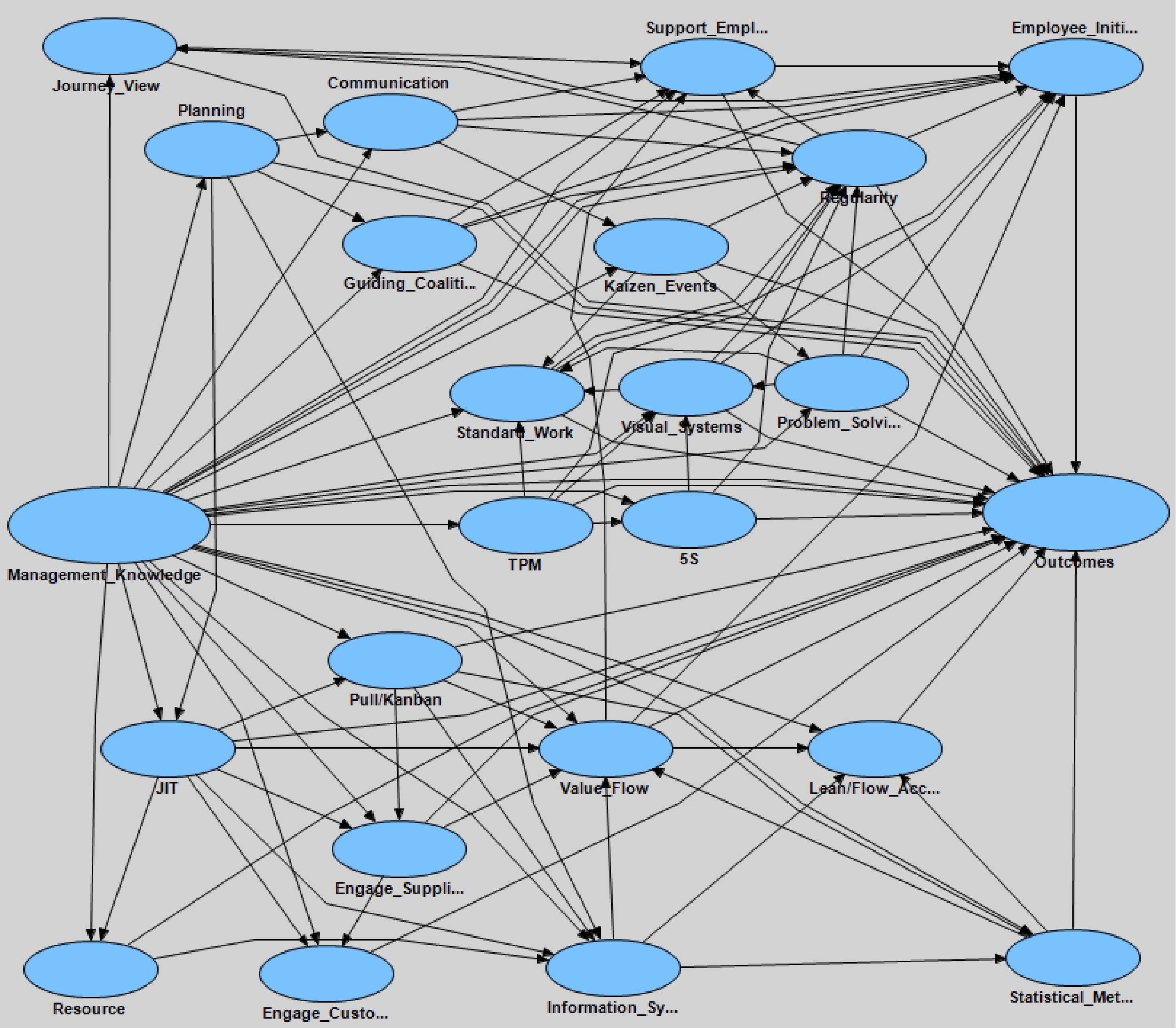

Figure 130 The Lean Knowledge-Based View (SEM K). This was the hypothesis model for the exploration of management's knowledge as the root cause for lean success. Further logical paths of causality were also tested once the basic structure of significant mediators was revealed.

Finally, adding the construct for management knowledge of lean formed the hypothesis model; that is the Lean Knowledge-Based View where management knowledge is presented as the root cause for success. See Figure 130.

8.2.7 Categorical Testing Procedure

Categories

Models were refined in explorative PLS-SEM for the general case (all lean responses) and according to four categories; this was a multi-sampling approach to moderation. The categories are below.

- Small business (11-100 employees)
- Medium-large business (101 – 500 employees)
- Low-variety high-volume manufacture
- High-variety low-volume manufacture

A bi-variate comparison of these categories is shown in Figure 131 and Figure 132. It is true that the low-volume high variety manufacture group is represented much more in the small business (11 to 100 employees) data than in the medium to large business (101 to 500 employees) data (Figure 131). But taking into account all the business sizes and organisation classifications (Figure 132), the following conclusions were made.

- Low-volume high-variety businesses were represented well across all business sizes.
- There is a balanced representation of product variety within the small business and the medium-large business data.
- However, the high-volume low-variety analysis was weighted towards larger businesses.

This was noted and the limitation accepted for the purpose of this work. There was insufficient data in this category to allow further analysis. Future work could investigate specific factors for high-volume low-variety manufacture in small business.

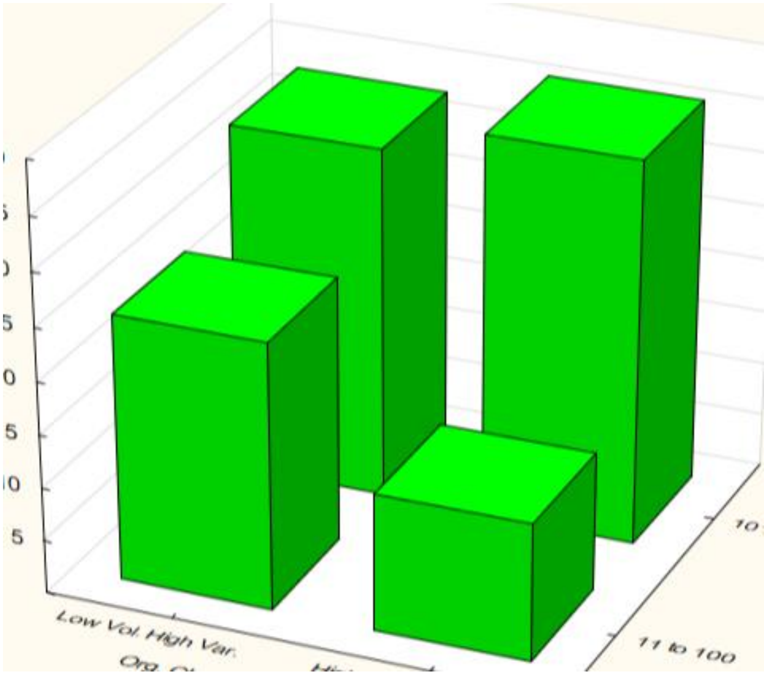

Figure 131 Business size and product mix classification bivariate histogram, for analysis categories.

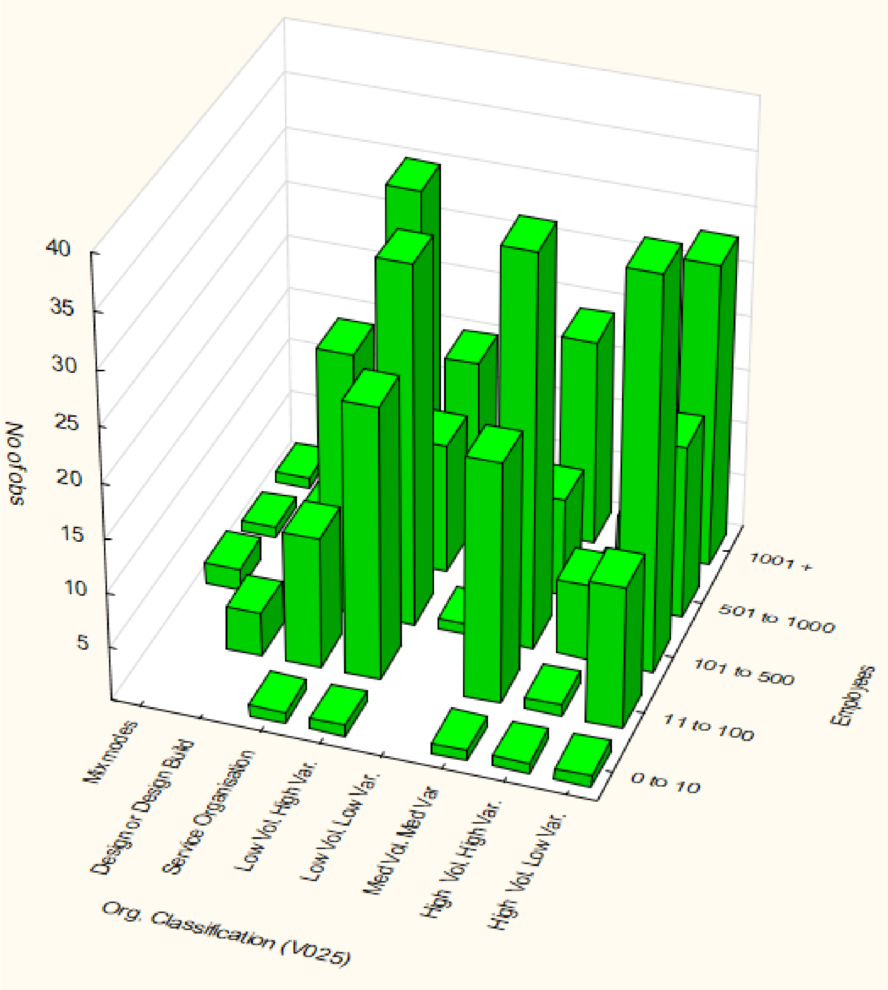

Figure 132 Business size and product mix classification bivariate histogram, for all categories.

Analysis Procedure

In the hypothesis SEM, the direct relationships between each constructs, management knowledge, and outcomes were included. Alternative logical relationship were also included. An iterative process was used to eliminate weak paths from the hypothesis model and add new logical relationships. The explorative procedure was:

1) Validated outer loading were >0.8.
2) Checked discriminant validity according to Fornell-Larker.
3) Iteratively bootstrapped the hypothesised paths for significance.
    a. Initial bootstrap with no sign changes, 300 iterations and paths t<0.7 were removed.
    b. Further bootstrapped 500 iteration with no sign changes and removed paths t<1.0.
    c. Conduct further bootstraps of 500 iterations with individual sign changes and removal of t<1.5.
4) Continued checking for alternate paths of causality (including direction of causality for strongest paths).
5) Final bootstrapping iterations (2000 then 5000 times) with individual sign changes until significance of remaining paths (p) reached specified acceptance level (α).
6) Checked variance explained by constructs and removed the insignificant constructs (i.e. R<0.1)
7) Validated quality of the final model.

8.3 SEM K—The Lean Knowledge-Based View

Explorative PLS-SEM of The Lean Knowledge-Based View resulted in multiple models. Models are presented for the generic case (all lean responses), small business (11-100 employees), medium-large business (101-500 employees), low-variety high-volume manufacture, and high-variety low-volume manufacture.

- The purpose of this exploration was to identify the main causal relationships, especially related to management knowledge and outcomes.
- The significance of each individual path is not discussed but rather the most relevant effects.

Many iterations insured that the internal models were well described.[148] The resultant models are presented without these many iterative steps. Specifics of the data set and any significant adjustments to indicator scales are noted. Quality tables are presented alongside the models and in the appendix. Output SEM diagrams from Smart PLS (Ringle, Christian M., Wende, Sven, & Will, Alexander, 2005) are used to present the exploration (e.g. Figure 135).

8.3.1 SEM K.1 Generic Case—All Lean Responses

The generic case (all lean and lean six sigma data, 90%+ complete) contained 393 cases. This large sample size meant a high significance level was set, α=0.01 (elsewhere α=0.05 was typical). It was confirmed that this was suitable where many spurious paths were observed at α=0.05 with β <0.1. A minimum β of 0.15 was also set.

Removed Constructs

Resources and Informations Systems were connected to the model by significant paths[149] (Planning->Resources, $p<0.00001$, β=0.3 and Lean/Flow Accounting->Information Systems $p<0.00001$, β=0.25) but were removed because firstly, no causal lines were found back into the model and secondly, variance of the constructs was not sufficiently explained (Resources R^2 was 0.09, and Information Systems R^2 was 0.06, both less than 0.1).

Statistical methods was the weakest explained construct (R^2=0.14). Statistical Methods -> Value Flow (β=0.14) was but retained to show that (although weak) there was a relationship to Outcomes through other factors.[150]

SEM K.1 Model Validation

The following tables are quality analysis outputs, see questionnaire One for details of interpretation (p. 182). The indicator loadings for SEM K.1 are included here as example. For the other SEM K models, only quality

[148] The models were well fitted, although with this kind of modelling, it might be possible to unveil additional affects.

[149] The paths had t-statistics of 6.4 and 4.7 respectively.

[150] A path that was borderline but removed was Management Knowledge to Kaizen Events, p=0.017, β=0.14.

overview and Fornell-Larker criterion are displayed with this text; indicator loadings, cross loadings, and path coefficients tables are in the appendix (p. 462).

	5S	Communication	Employee Initiatives	Engage Customers	Engage Suppliers	Guiding Coalition	JIT	Journey View	Kaizen Events	Lean/Flow Accounting	Management Knowledge	Outcomes	Planning	Problem Solving (Simple)	Pull/Kanban	Regularity	Standard Work	Statistical Methods	Support Employee	TPM	Value Flow	Visual Systems
5S V086 5S System	1.00																					
COM V050 Mngmnt effective co		0.88																				
COM V051 Mngmnt vivid comm.		0.91																				
COM V052 Mngmnt comm. staff		0.91																				
COM V053 Mngmnt vivid com. s		0.86																				
EE V041 Worker Initiatives			0.82																			
EE V048 Easy for suggestion/imp			0.83																			
EE V057 Involved all Staff			0.83																			
ENC V101 Engaging customers				1.00																		
ENS V100 Engaging suppliers					1.00																	
GC V077 Guiding coalition suppor						1.00																
JIT V087 Just In Time Manufactu							1.00															
JV V031 JourneyView								1.00														
KAI V090 Kaizen									1.00													
LAC V058 Lean/flow accounting										1.00												
MK V067 Mngmnt understood to											0.84											
MK V068 Mngmnt understood as											0.87											
MK V105 Mngmnt contin. to lear											0.82											
OC V016 Performance Enhanced												0.89										
OC V040 Sustained Imp.												0.83										
OC V015 Competitive Advantag												0.86										
PL V047 Mngmnt planned well													1.00									
PR V091 5 Whys														0.91								
PR V092 Simple problem solving														0.90								
PUL V094 Pull Systems															0.91							
PUL V095 Kanban															0.90							
REG V072 Small wins prominent																0.78						
REG V078 Program/Structure/Re																0.86						
STA V096 Statistical Methods																		1.00				
STW V080 Standard work develo																	1.00					
SU V075 Growth mindset																			0.89			
SU V079 Individual support in adj																			0.85			
TPM V089 Total Productive Mai																				1.00		
V093 DefiningValue																					0.89	
V097 MappingValue Stream																					0.87	
VS V098 Visual Systems																						1.00

Basic criterion for loading is >0.7. Lower loadings are accepted in exploratory work and removal of slightly lower loadings in PLS SEM is discouraged to support

Figure 133 SEM K.1 indicator loadings in outer model.

QualityOverview

	AVE	Composite Reliability	Cronbachs Alpha	Redundancy	R Square	Communality
Significance criteria	*>0.5*	*>0.6**	*>0.7***		*>0.1*	
Minimum	*0.68*	*0.87*	*0.77*		*0.21*	*0.68*
5S	1.00	1.00	1.00	0.24	0.37	
Communication	0.79	0.94	0.91	0.29	0.58	0.79
Employee Initiatives (Enabled)	0.68	0.87	0.77	0.27	0.71	0.68
Engage Customers	1.00	1.00	1.00	0.12	0.40	
Engage Suppliers	1.00	1.00	1.00	0.17	0.34	
Guiding Coalition	1.00	1.00	1.00	0.18	0.22	
JIT	1.00	1.00	1.00	0.10	0.21	
Journey View	1.00	1.00	1.00	0.23	0.28	
Kaizen Events	1.00	1.00	1.00	0.23	0.33	
Lean/Flow Accounting	1.00	1.00	1.00	0.21	0.21	
Management Knowledge	0.71	0.88	0.80			0.71
Outcomes	0.74	0.90	0.83	-0.06	0.52	0.74
Planning	1.00	1.00	1.00	0.32	0.32	
Problem Solving (Simple)	0.82	0.90	0.78	0.15	0.43	0.82
Pull/Kanban	0.83	0.90	0.79	0.36	0.47	0.83
Regularity	0.67	0.80	0.52	0.12	0.51	0.67
Standard Work	1.00	1.00	1.00	0.24	0.36	
Statistical Methods	1.00	1.00	1.00	0.07	0.15	
Support Employees	0.76	0.86	0.68	0.25	0.53	0.76
TPM	1.00	1.00	1.00	0.23	0.40	
Value Flow	0.78	0.87	0.71	0.10	0.35	0.78
Visual Systems	1.00	1.00	1.00	0.25	0.33	

Fornell-Larcker Criterion (Fornell&Larcker,1981)

	5S	Communication	Employee Initiatives (Enabled)	Engage Customers	Engage Suppliers	Guiding Coalition	JIT	Journey View	Kaizen Events	Lean/Flow Accounting	Management Knowledge	Outcomes	Planning	Problem Solving (Simple)	Pull/Kanban	Regularity	Standard Work	Statistical Methods	Support Employees	TPM	Value Flow	Visual Systems
5S	**N/A**																					
Communication	0.26	**0.89**																				
Employee Initiatives (Enabled)	0.40	0.73	**0.83**																			
Engage Customers	0.06	0.44	0.39	**N/A**																		
Engage Suppliers	0.22	0.46	0.41	0.59	**N/A**																	
Guiding Coalition	0.19	0.42	0.49	0.19	0.22	**N/A**																
JIT	0.48	0.40	0.43	0.26	0.48	0.19	**N/A**															
Journey View	0.29	0.39	0.54	0.25	0.19	0.35	0.30	**N/A**														
Kaizen Events	0.48	0.31	0.36	0.18	0.17	0.21	0.44	0.24	**N/A**													
Lean/Flow Accounting	0.20	0.40	0.42	0.29	0.36	0.11	0.35	0.19	0.25	**N/A**												
Management Knowledge	0.30	0.66	0.72	0.39	0.42	0.44	0.43	0.49	0.29	0.46	**0.84**											
Outcomes	0.16	0.58	0.66	0.44	0.44	0.35	0.40	0.40	0.22	0.38	0.57	**0.86**										
Planning	0.19	0.69	0.62	0.33	0.35	0.39	0.35	0.30	0.20	0.31	0.56	0.45	**N/A**									
Problem Solving (Simple)	0.43	0.40	0.54	0.32	0.28	0.38	0.35	0.47	0.50	0.25	0.50	0.38	0.36	**0.91**								
Pull/Kanban	0.41	0.41	0.40	0.23	0.47	0.23	0.66	0.20	0.48	0.38	0.44	0.43	0.34	0.42	**0.91**							
Regularity	0.27	0.52	0.58	0.29	0.29	0.60	0.27	0.43	0.35	0.17	0.51	0.43	0.38	0.47	0.25	**0.82**						
Standard Work	0.36	0.44	0.54	0.28	0.35	0.42	0.35	0.36	0.31	0.36	0.52	0.44	0.34	0.40	0.38	0.52	**N/A**					
Statistical Methods	0.20	0.24	0.17	0.25	0.38	0.20	0.22	0.14	0.16	0.28	0.28	0.28	0.20	0.32	0.35	0.24	0.26	**N/A**				
Support Employees	0.23	0.58	0.69	0.39	0.40	0.53	0.31	0.41	0.34	0.30	0.63	0.53	0.45	0.49	0.39	0.59	0.48	0.29	**0.87**			
TPM	0.52	0.41	0.41	0.25	0.38	0.23	0.55	0.23	0.51	0.40	0.41	0.32	0.27	0.47	0.52	0.33	0.40	0.32	0.31	**N/A**		
Value Flow	0.25	0.44	0.40	0.41	0.41	0.37	0.38	0.29	0.42	0.25	0.38	0.43	0.29	0.48	0.48	0.41	0.33	0.35	0.50	0.35	**0.88**	
Visual Systems	0.53	0.42	0.52	0.25	0.35	0.40	0.42	0.46	0.33	0.24	0.52	0.42	0.32	0.57	0.45	0.46	0.53	0.22	0.46	0.47	0.45	**N/A**

Latent variable correlations compared with √(AVE), i.e. check √(AVE)> factor loading, Bold=√(AVE)

**Composite Reliability >0.6 for exploratory research or >0.7 for developed research.*

***Cronbachs Alpha is included for reference. Composite reliability is prefered over Conbach's Alpha for PLS-SEM. Refer: Hair J. F. 2011, PLS-SEM: Indeed a Silver Bullet*

Av R^2	*Av Com.*
0.38	*0.75*
Gof =	*0.54*

Goodness of fit Calculation: Gof = SQRT((Avg R^2)(Avg Com.))*

Gof > 0.31 recommended

Figure 134 SEM K.1 quality overview and Fornell-Larcker criterion.

SEM K.1 Resultant Model

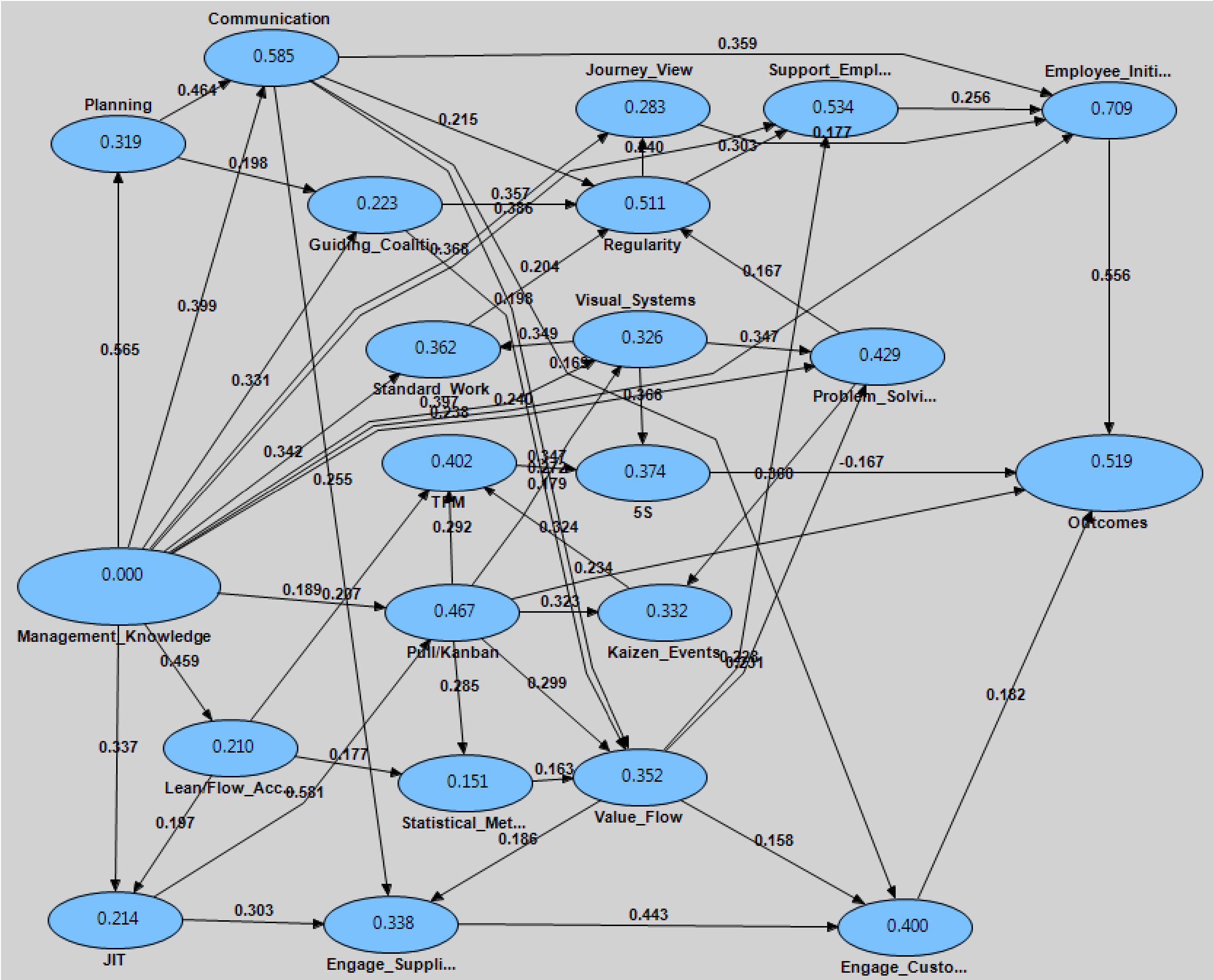

Figure 135 SEM K.1 Resultant model of the Lean Knowledge-Based View for the generic lean case (393 lean and lean six sigma cases, 90%+ complete, all paths significant to p<0.01, bootstrapped 5000 times, individual sign changes allowed).

Negative relationships and p>0.01 highlighted	Original Sample (β)	Sample Mean	Standard Deviation	Standard Error	T Statistics	p -value (Significance)
Management Knowledge->Communication	0.40	0.40	0.04	0.04	9.54	0.00000
Management Knowledge->Employee Initiatives (Enabled)	0.24	0.24	0.04	0.04	5.38	0.00000
Management Knowledge->Guiding Coalition	0.33	0.33	0.06	0.06	5.95	0.00000
Management Knowledge->JIT	0.34	0.34	0.05	0.05	7.34	0.00000
Management Knowledge->Journey View	0.37	0.37	0.05	0.05	7.95	0.00000
Management Knowledge->Lean/Flow Accounting	0.46	0.46	0.04	0.04	11.71	0.00000
Management Knowledge->Planning	0.56	0.56	0.04	0.04	14.95	0.00000
Management Knowledge->Problem Solving (Simple)	0.24	0.24	0.04	0.04	5.62	0.00000
Management Knowledge->Pull/Kanban	0.19	0.19	0.04	0.04	4.53	0.00001
Management Knowledge->Standard Work	0.34	0.34	0.05	0.05	6.51	0.00000
Management Knowledge->Support Employees	0.39	0.38	0.04	0.04	9.12	0.00000
Management Knowledge->Visual Systems	0.40	0.40	0.05	0.05	8.22	0.00000

Figure 136 SEM K.1 direct effects of management Knowledge

Negative relationships and p>0.01 highlighted	Original Sample (β)	Sample Mean	Standard Deviation	Standard Error	T Statistics	p -value (Significance)
Statistical Methods->Value Flow	0.16	0.16	0.05	0.05	3.16	0.00169
Lean/Flow Accounting->Statistical Methods	0.18	0.18	0.05	0.05	3.23	0.00135
Value Flow->Engage Customers	0.16	0.16	0.05	0.05	3.31	0.00101
Communication->Value Flow	0.20	0.20	0.06	0.06	3.36	0.00087
Communication->Engage Customers	0.17	0.17	0.05	0.05	3.43	0.00067
Value Flow->Engage Suppliers	0.19	0.18	0.05	0.05	3.48	0.00055
5S->Outcomes	-0.17	-0.17	0.05	0.05	3.55	0.00043

Figure 137 SEM K.1 least significant paths (includes the only negative relationship observed).

Negative relationships and p>0.01 highlighted	Original Sample (β)	Sample Mean	Standard Deviation	Standard Error	T Statistics	p -value (Significance)
JIT->Pull/Kanban	0.58	0.58	0.04	0.04	14.68	0.00000
Management Knowledge->Planning	0.56	0.56	0.04	0.04	14.95	0.00000
Employee Initiatives (Enabled)->Outcomes	0.56	0.56	0.04	0.04	13.26	0.00000
Planning->Communication	0.46	0.46	0.04	0.04	11.44	0.00000
Management Knowledge->Lean/Flow Accounting	0.46	0.46	0.04	0.04	11.71	0.00000

Figure 138 SEM K.1 five largest path coefficients.

Negative relationships and p>0.01 highlighted	Original Sample (β)	Sample Mean	Standard Deviation	Standard Error	T Statistics	p -value (Significance)
Employee Initiatives (Enabled)->Outcomes	0.56	0.56	0.04	0.04	13.26	0.00000
Pull/Kanban->Outcomes	0.23	0.23	0.04	0.04	5.32	0.00000
Engage Customers->Outcomes	0.18	0.18	0.04	0.04	4.71	0.00000
5S->Outcomes	-0.17	-0.17	0.05	0.05	3.55	0.00043

Figure 139 SEM K.1 direct effects on Outcomes.

SEM K.1 Outcomes

Given the explorative nature, the generic model significantly explained Outcomes[151] with R^2 of 0.52 achieved. The following results were significant to this work.

- The strongest direct relationship with Outcomes is from Employee Initiatives (β=0.56).
- Pull/Kanban had the second strongest direct relationship with Outcomes. But the path coefficient (β=0.23), was less than half of Employee Initiatives-> Outcomes (β=0.56).
- The strongest chain of causality is from Management Knowledge through Planning and Communication to Employee initiatives.
- The key components of implementation were explained directly or indirectly by Management Knowledge.

[151] As earlier discussed: R^2 results are typically categorised as substantial, moderate, and weak. One scale is 0.67, 0.33, and 0.19 (Chin, 1998b; Henseler et al., 2009) and a similar alternative 0.75, 0.50, or 0.25 (market research Joe F. Hair, Ringle, & Sarstedt, 2011). Moderate values are deemed acceptable if only a few latent variables are exogenous. If several latent variables are acting substantial values are suggested (Henseler et al., 2009). This criterion is dependent on context, e.g. in consumer behaviour 0.2 is considered high (Joe F. Hair et al., 2011). That said, a minimum of 0.1 is a reasonable guideline (Camison & Villar-López, 2012; ref. Falk & Miller, 1992).

- Additional strong paths occur from Regularity through Journey View or Support Employees to Employee Initiatives.
- Another positive path to Outcomes is from Engaging Customers (β=0.18).
- Engaging Customers to Outcomes is developed through Communication and JIT via Engaging Suppliers.
- 5S is linked to TPM (β=0.35) as well as Visual Systems (β=0.37).
- A negative path is observed from the method 5S to Outcomes.
- The negative path implies an improper overuse of 5S, and that the direct effect of 5S is negative, without supporting and enabling employee.
- In general the advanced processes, represented strongly by Pull/Kanban are mediated to Outcomes by the application of simple techniques (represented by TPM, 5S, Visual Systems, and Standard Work). The effects of all these methods are mediated to Outcomes through the chain Regularity, the Journey View, Support for Employees and Employee Initiatives.

This SEM showed that the effects of leadership and enabling employees on outcomes were significant by themselves, the strongest in each model. These were also mediators between the lean methods and success.

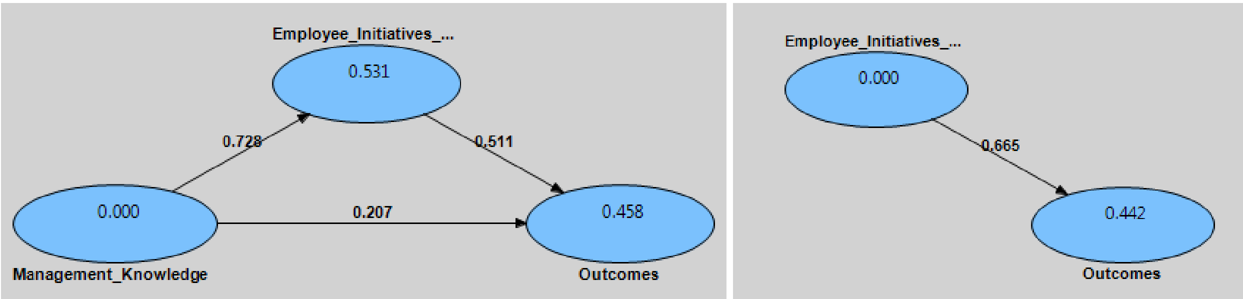

Figure 140 SEM K.1 simplified representation: Management Knowledge and Employee Initiatives (enabled) acting on Outcomes.

The significant effects of leadership enabling employee initiatives are represented in the above simplified SEMs (Figure 140). These SEMs show:

- 46% of the variance in Outcomes can be explained by the partial mediation of Management Knowledge to Outcomes by Employee Initiatives (compared with the 52% explained in full SEM K.1).
- Employee Initiatives by itself explains 44% of the Outcomes.

The majority of the variance in Outcomes (explained by SEM K.1) can be explained by management knowledge expressed through the enabling of employee initiatives.

8.3.2 SEM K.2 Medium to Large Business (101-500 Employees)

The medium - large business data set (employees 101-500, 90%+ complete) contained 146 cases. A typical α of 0.05 was set.

Removed Constructs

Information Systems and Resources were removed. Resources indicators loaded unevenly (Technology Capability 0.8, and Staff Capability 0.9). In other constructs this may have been acceptable but an over influence of personnel aspects is undesirable in this construct; the construct needed to represent the development of general resources as much as possible. Resources were reduced to Technology Resources as a single indicator construct. Technology Resources and Information Systems only had weak relationships to the model ($\beta<0.2$) and were weakly explained in the model ($R^2=0.14$ and 0.05).[152] They were removed. See Figure 140.

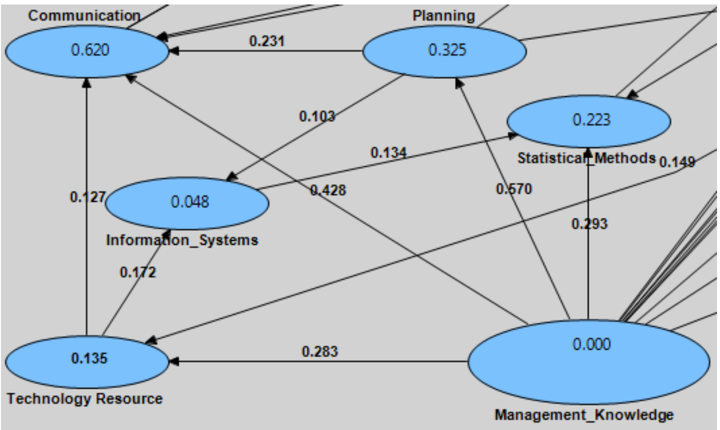

Figure 141 Relationships with Technology Resources and Information Systems in SEM K.2.

SEM K.2 Model Validation

The following table gives an overview of the resultant models quality, see questionnaire One for details of interpretation (p. 182).

[152] A direct relationship from Information Systems only described 2% of Statistical Methods variance.

Quality Overview

	AVE	Composite Reliability	Cronbachs Alpha	Redundancy	R Square	Communality
Significancecriteria	*>0.5*	*>0.6**	*>0.7***		*>0.1*	
Minimum	*0.73*	*0.89*	*0.81*		*0.17*	*0.73*
5S	1.00	1.00	1.00	0.15	0.26	
Communication	0.76	0.93	0.89	0.10	0.59	0.76
Employee Initiatives (Enabled)	0.73	0.89	0.81	0.06	0.71	0.73
Engage Customers	1.00	1.00	1.00	0.32	0.54	
Engage Suppliers	1.00	1.00	1.00	0.31	0.44	
Guiding Coalition	1.00	1.00	1.00	0.18	0.23	
JIT	1.00	1.00	1.00	0.13	0.17	
Journey View	1.00	1.00	1.00	0.24	0.38	
Kaizen Events	1.00	1.00	1.00	0.16	0.22	
Lean/Flow Accounting	1.00	1.00	1.00	0.15	0.20	
Management Knowledge	0.70	0.87	0.79			0.70
Outcomes	0.71	0.88	0.79	0.26	0.57	0.71
Planning	1.00	1.00	1.00	0.32	0.32	
Problem Solving (Simple)	0.81	0.89	0.76	0.22	0.31	0.81
Pull/Kanban	0.85	0.92	0.82	0.46	0.54	0.85
Regularity	0.69	0.82	0.55	0.19	0.62	0.69
Standard Work	1.00	1.00	1.00	0.16	0.29	
Statistical Methods	1.00	1.00	1.00	0.14	0.20	
Support Employees	0.75	0.86	0.67	0.23	0.59	0.75
TPM	1.00	1.00	1.00	0.24	0.40	
Value Flow	0.80	0.89	0.75	0.14	0.37	0.80
Visual Systems	1.00	1.00	1.00	0.15	0.47	

Fornell-Larcker Criterion (Fornell & Larcker,1981)

	5S	Communication	Employee Initiatives (Enabled	Engage Customers	Engage Suppliers	Guiding Coalition	JIT	Journey View	Kaizen Events	Lean/Flow Accounting	Management Knowledge	Outcomes	Planning	Problem Solving (Simple)	Pull/Kanban	Regularity	Standard Work	Statistical Methods	Support Employees	TPM	Value Flow	Visual Systems
5S	**N/A**																					
Communication	0.13	**0.87**																				
Employee Initiatives (Enabled)	0.34	0.73	**0.85**																			
Engage Customers	0.03	0.63	0.39	**N/A**																		
Engage Suppliers	0.15	0.57	0.40	0.67	**N/A**																	
Guiding Coalition	0.18	0.39	0.45	0.14	0.20	**N/A**																
JIT	0.42	0.38	0.37	0.28	0.45	0.14	**N/A**															
Journey View	0.26	0.40	0.56	0.19	0.17	0.26	0.32	**N/A**														
Kaizen Events	0.42	0.23	0.27	0.14	0.08	0.17	0.47	0.23	**N/A**													
Lean/Flow Accounting	-0.09	0.46	0.37	0.26	0.32	0.11	0.21	0.07	0.10	**N/A**												
Management Knowledge	0.20	0.71	0.71	0.43	0.41	0.43	0.38	0.54	0.23	0.39	**0.84**											
Outcomes	0.23	0.61	0.64	0.40	0.43	0.28	0.46	0.45	0.28	0.38	0.51	**0.84**										
Planning	0.00	0.59	0.57	0.37	0.30	0.36	0.35	0.33	0.11	0.33	0.57	0.37	**N/A**									
Problem Solving (Simple)	0.44	0.40	0.58	0.31	0.25	0.40	0.44	0.48	0.52	0.08	0.51	0.41	0.33	**0.90**								
Pull/Kanban	0.30	0.35	0.34	0.32	0.51	0.20	0.73	0.17	0.42	0.33	0.35	0.55	0.31	0.39	**0.92**							
Regularity	0.25	0.55	0.65	0.32	0.32	0.62	0.32	0.53	0.28	0.15	0.64	0.44	0.49	0.58	0.24	**0.83**						
Standard Work	0.32	0.47	0.59	0.36	0.42	0.55	0.37	0.42	0.30	0.30	0.55	0.56	0.36	0.48	0.44	0.63	**N/A**					
Statistical Methods	0.12	0.37	0.23	0.28	0.36	0.24	0.25	0.17	0.24	0.24	0.39	0.32	0.26	0.31	0.36	0.39	0.40	**N/A**				
Support Employees	0.18	0.67	0.73	0.45	0.38	0.50	0.29	0.43	0.22	0.26	0.67	0.57	0.47	0.48	0.31	0.62	0.52	0.41	**0.87**			
TPM	0.46	0.46	0.47	0.26	0.37	0.24	0.55	0.26	0.51	0.21	0.45	0.44	0.28	0.51	0.46	0.41	0.42	0.31	0.27	**N/A**		
Value Flow	0.16	0.39	0.33	0.45	0.31	0.34	0.34	0.20	0.40	0.21	0.34	0.45	0.25	0.52	0.50	0.43	0.40	0.36	0.46	0.30	**0.89**	
Visual Systems	0.42	0.37	0.51	0.29	0.41	0.39	0.34	0.44	0.19	0.07	0.53	0.48	0.22	0.51	0.43	0.51	0.48	0.18	0.49	0.42	0.42	**N/A**

**Composite Reliability >0.6 for exploratory research or >0.7 for developed research.*
***Cronbachs Alpha is included for reference. Composite reliability is prefered over Conbach's Alpha for PLS-SEM.*
Refer: Hair J. F. 2011. PLS-SEM: Indeed a Silver

Latent variable correlations compared with √(AVE), i.e. check √(AVE)>factor loading, Bold=√(AVE)

Av R^2	***Av Com.***
0.40	*0.75*
Gof =	*0.55*

Goodness of fit Calculation: Gof = SQRT((Avg R^2)(Avg Com.))*
Gof > 0.31 recommended

Figure 142 SEM K.2 quality overview and Fornell - Larcker criterion

SEM K.2 Resultant Model

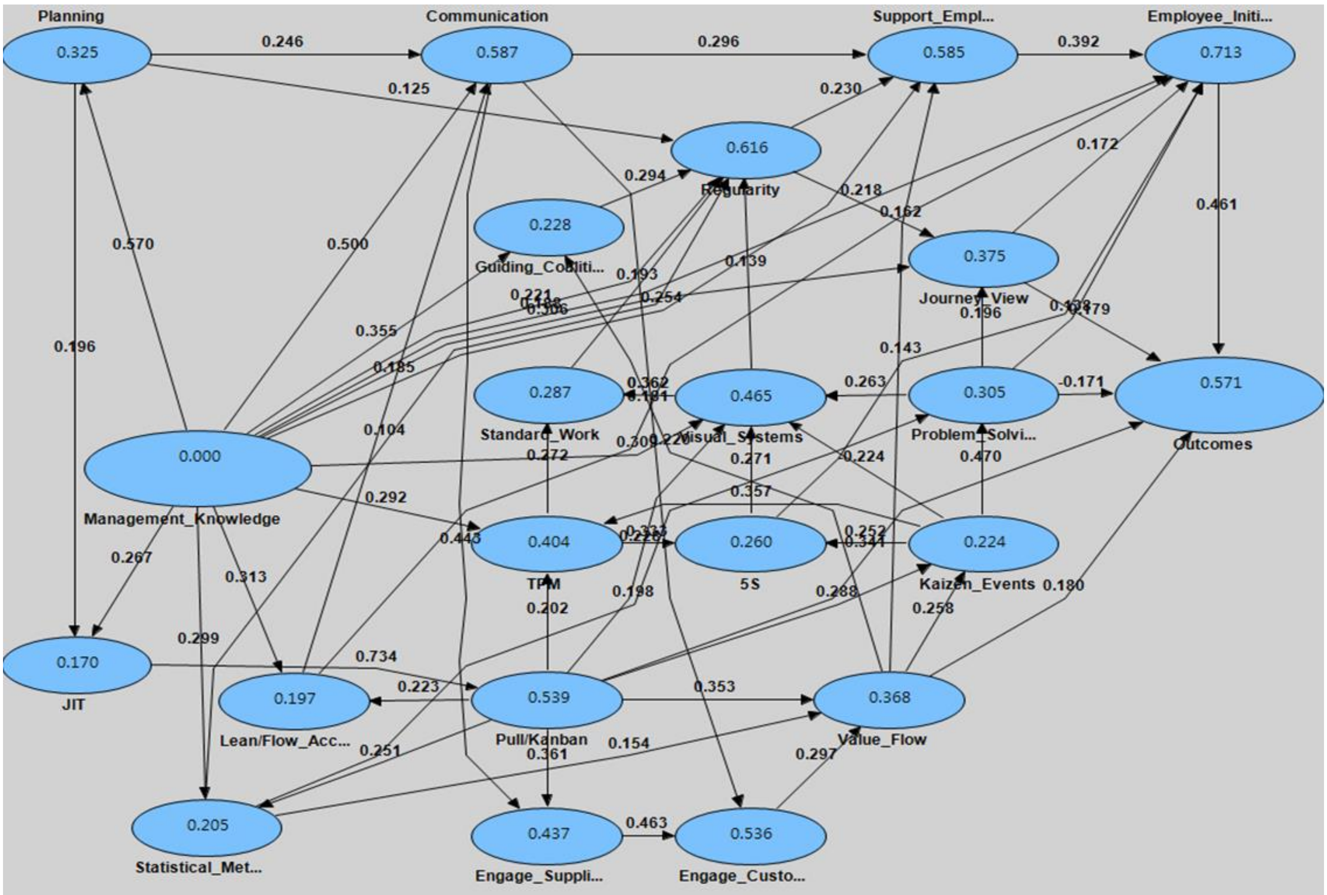

Figure 143 SEM K.2 resultant model of the Lean Knowledge-Based View for the medium to large business case (101-500 employees, 146 lean and lean six sigma, 90%+ complete, all paths significant with p<0.05, bootstrapped 5000 times, individual sign changes allowed).

Negative relationships and p>0.01 highlighted	Original Sample (β)	Sample Mean	Standard Deviation	Standard Error	T Statistics	p -value (Significance)
Management Knowledge->Communication	0.50	0.50	0.08	0.08	6.47	0.00000
Management Knowledge->Employee Initiatives (Enabled)	0.19	0.19	0.07	0.07	2.70	0.00779
Management Knowledge->Guiding Coalition	0.35	0.36	0.10	0.10	3.52	0.00059
Management Knowledge->JIT	0.27	0.27	0.09	0.09	2.96	0.00359
Management Knowledge->Journey View	0.31	0.31	0.08	0.08	4.05	0.00008
Management Knowledge->Lean/Flow Accounting	0.31	0.31	0.07	0.07	4.28	0.00003
Management Knowledge->Planning	0.57	0.57	0.07	0.07	8.53	0.00000
Management Knowledge->Regularity	0.22	0.22	0.07	0.07	2.99	0.00324
Management Knowledge->Statistical Methods	0.30	0.30	0.07	0.07	4.17	0.00005
Management Knowledge->Support Employees	0.25	0.25	0.09	0.09	2.86	0.00484
Management Knowledge->TPM	0.29	0.29	0.06	0.06	4.59	0.00001
Management Knowledge->Visual Systems	0.31	0.31	0.07	0.07	4.56	0.00001

Figure 144 SEM K.2 direct effects of management Knowledge

Negative relationships and p>0.01 highlighted	Original Sample (β)	Sample Mean	Standard Deviation	Standard Error	T Statistics	p -value (Significance)
Statistical Methods->Regularity	0.10	0.10	0.05	0.05	1.93	0.05501
Visual Systems->Regularity	0.14	0.14	0.07	0.07	1.95	0.05329
Planning->Regularity	0.12	0.13	0.06	0.06	1.97	0.05132
Problem Solving (Simple)->Outcomes	-0.17	-0.17	0.09	0.09	2.00	0.04736
Statistical Methods->Value Flow	0.15	0.15	0.07	0.07	2.14	0.03399

Figure 145 SEM K.2 five least significant paths.

Negative relationships and p>0.01 highlighted	Original Sample (β)	Sample Mean	Standard Deviation	Standard Error	T Statistics	p -value (Significance)
JIT->Pull/Kanban	0.73	0.73	0.05	0.05	14.87	0.00000
Management Knowledge->Planning	0.57	0.57	0.07	0.07	8.53	0.00000
Management Knowledge->Communication	0.50	0.50	0.08	0.08	6.47	0.00000
Kaizen Events->Problem Solving (Simple)	0.47	0.47	0.07	0.07	6.71	0.00000
Engage Suppliers->Engage Customers	0.46	0.46	0.08	0.08	5.97	0.00000
Employee Initiatives (Enabled)->Outcomes	0.46	0.46	0.09	0.09	5.34	0.00000
Communication->Engage Suppliers	0.44	0.44	0.06	0.06	7.95	0.00000

Figure 146 SEM K.2 largest path coefficients.

Negative relationships and p>0.01 highlighted	Original Sample (β)	Sample Mean	Standard Deviation	Standard Error	T Statistics	p -value (Significance)
Employee Initiatives (Enabled)->Outcomes	0.46	0.46	0.09	0.09	5.34	0.00000
Pull/Kanban->Outcomes	0.34	0.34	0.07	0.07	4.77	0.00000
Value Flow->Outcomes	0.18	0.18	0.08	0.08	2.34	0.02080
Journey View->Outcomes	0.18	0.18	0.07	0.07	2.54	0.01216
Problem Solving (Simple)->Outcomes	-0.17	-0.17	0.09	0.09	2.00	0.04736

Figure 147 SEM K.2 direct effects on Outcomes.

Negative relationships and p>0.01 highlighted	Original Sample (β)	Sample Mean	Standard Deviation	Standard Error	T Statistics	p -value (Significance)
Kaizen Events->Visual Systems	-0.22	-0.23	0.08	0.08	2.81	0.00559
Problem Solving (Simple)->Outcomes	-0.17	-0.17	0.09	0.09	2.00	0.04736

Figure 148 SEM K.2 negative relationships observed.

SEM K.2 Outcomes

Given the explorative nature of this analysis, the generic model strongly explained Outcomes with R^2 of 0.57 being achieved. The following results were significant to this work.

- The strongest direct relationship with Outcomes was from Employee Initiatives (β=0.46).
- Pull/Kanban had the second strongest direct relationship with Outcomes. The path coefficient (β=0.34) was 73% of Employee Initiatives-> Outcomes.
- The strongest chain of causality is from Management Knowledge through Planning, Communication to Employee initiatives.

- Additional strong paths occur from Regularity through Journey View or Support Employees to Employee Initiatives (enabled).
- The key components of implementation are explained directly or indirectly by Management Knowledge.
- Two weak direct paths to Outcomes came from the Journey View and Value Flow (defining value and mapping the value stream), β=0.18.
- A negative path was observed direct from Problem Solving to Outcomes (β=-0.17).
- This implies an overuse of simple problem solving methods and shows that the direct effect on outcomes apart from support and enablement of employee initiatives is not beneficial to success.
- In general, the advanced processes represented strongly by Pull/Kanban are mediated to Outcomes by the application of simple techniques (represented by TPM, 5S, Visual Systems and Standard Work). The effects of all these methods are mediated to Outcomes through Regularity, the Journey View, Support for Employees, and Employee Initiatives.

This SEM showed that the effects of leadership and enabling employees on outcomes were significant by themselves, the strongest in each model. These were also mediators between the lean methods and success.

Figure 149 SEM K.2 simplified representation: Management Knowledge and Employee Initiatives (enabled) acting on Outcomes. Management Knowledge to Outcomes was insignificant and was removed (t=1.5 after bootstrapped 5000 times, individual sign changes).

The significant effects of leadership enabling employee initiatives are represented in the simplified SEMs, Figure 149. These SEMs show:

- 38% of variance of Outcomes can be explained by the full mediation of Management Knowledge to Outcomes by Employee Initiatives (67% of the 57% variance [R^2=0.57] explained in full SEM K.2).

The majority of the variance in Outcomes (explained by SEM K.2) can be explained by management knowledge expressed through the enabling of employee initiatives.

8.3.3 SEM K.3 Small Business (11-100 Employees)

The small business data set (all lean and lean six sigma data, employees 11-100, 90%+ complete) contained 80 cases. This was suitable by ten times paths rule. There was a maximum of seven paths to any one construct. A typical α level of 0.05 was set.

Removed Constructs

Resources and Information systems fell out of the iterated model with no significant relationships.

SEM K.3 Model Validation

The following table is an overview of model quality, see questionnaire One for details of interpretation (p. 182).

Quality Overview / **Fornell-Larcker Criterion (Fornell & Larcker,1981)**

	AVE	Composite Reliability	Cronbachs Alpha	Redundancy	R Square	Communality	5S	Communication	Employee Initiatives (Enabled)	Engage Customers	Engage Suppliers	Guiding Coalition	JIT	Journey View	Kaizen Events	Lean/Flow Accounting	Management Knowledge	Outcomes	Planning	Problem Solving (Simple)	Pull/Kanban	Regularity	Standard Work	Statistical Methods	Support Employees	TPM	Value Flow	Visual Systems
Significancecriteria	*>0.5*	*>0.6**	*>0.7***		*>0.1*																							
Minimum	*0.69*	*0.87*	*0.78*		*0.09*	*0.69*																						
5S	1.00	1.00	1.00	0.18	0.41		**N/A**																					
Communication	0.72	0.91	0.87	0.12	0.56	0.72	0.44	**0.85**																				
Employee Initiatives (Enabled)	0.69	0.87	0.78	0.24	0.75	0.69	0.45	0.67	**0.83**																			
Engage Customers	1.00	1.00	1.00	0.33	0.42		0.05	0.33	0.42	**N/A**																		
Engage Suppliers	1.00	1.00	1.00	0.23	0.27		0.22	0.30	0.41	0.57	**N/A**																	
Guiding Coalition	1.00	1.00	1.00	0.23	0.23		0.25	0.42	0.50	0.35	0.27	**N/A**																
JIT	1.00	1.00	1.00	0.09	0.09		0.32	0.27	0.26	0.12	0.48	0.08	**N/A**															
Journey View	1.00	1.00	1.00	0.20	0.37		0.38	0.22	0.49	0.15	0.17	0.20	0.24	**N/A**														
Kaizen Events	1.00	1.00	1.00	0.13	0.21		0.45	0.26	0.30	0.00	0.05	0.12	0.36	0.09	**N/A**													
Lean/Flow Accounting	1.00	1.00	1.00	0.18	0.23		0.12	0.31	0.45	0.31	0.43	0.19	0.22	0.24	0.16	**N/A**												
Management Knowledge	0.69	0.87	0.77			0.69	0.33	0.48	0.71	0.34	0.33	0.48	0.27	0.42	0.21	0.34	**0.83**											
Outcomes	0.76	0.91	0.84	-0.21	0.71	0.76	0.16	0.55	0.73	0.49	0.34	0.46	0.25	0.38	0.18	0.34	0.56	**0.87**										
Planning	1.00	1.00	1.00	0.13	0.22		0.35	0.72	0.56	0.36	0.39	0.39	0.30	0.00	0.18	0.25	0.41	0.48	**N/A**									
Problem Solving (Simple)	0.80	0.89	0.75	0.07	0.45	0.80	0.41	0.30	0.52	0.22	0.22	0.27	0.06	0.35	0.34	0.35	0.45	0.26	0.30	**0.89**								
Pull/Kanban	0.72	0.84	0.63	0.10	0.20	0.72	0.40	0.30	0.29	0.14	0.29	0.29	0.37	0.10	0.56	0.25	0.33	0.29	0.21	0.18	**0.85**							
Regularity	0.65	0.78	0.47	0.14	0.39	0.65	0.31	0.50	0.58	0.35	0.17	0.54	0.05	0.26	0.31	0.24	0.40	0.50	0.35	0.35	0.17	**0.80**						
Standard Work	1.00	1.00	1.00	0.44	0.44		0.40	0.31	0.47	0.41	0.29	0.35	0.19	0.32	0.16	0.25	0.43	0.49	0.13	0.41	0.15	0.36	**N/A**					
Statistical Methods	1.00	1.00	1.00	0.11	0.11		0.18	-0.07	-0.03	0.24	0.30	0.15	0.11	0.13	0.03	0.13	-0.05	-0.01	0.00	0.24	0.20	0.13	0.11	**N/A**				
Support Employees	0.72	0.84	0.62	0.11	0.52	0.72	0.31	0.38	0.64	0.48	0.32	0.49	0.07	0.28	0.31	0.21	0.51	0.52	0.35	0.47	0.34	0.65	0.44	0.24	**0.85**			
TPM	1.00	1.00	1.00	0.19	0.31		0.46	0.18	0.19	0.11	0.13	0.18	0.34	0.12	0.49	0.30	0.19	0.00	0.14	0.36	0.35	0.18	0.24	0.21	0.17	**N/A**		
Value Flow	0.71	0.83	0.61	0.18	0.42	0.71	0.29	0.41	0.35	0.52	0.42	0.23	0.32	0.22	0.27	0.24	0.32	0.37	0.27	0.43	0.46	0.29	0.37	0.33	0.42	0.16	**0.84**	
Visual Systems	1.00	1.00	1.00	0.13	0.39		0.58	0.52	0.62	0.42	0.39	0.34	0.37	0.41	0.32	0.38	0.53	0.48	0.41	0.61	0.23	0.41	0.66	0.12	0.41	0.39	0.57	**N/A**

**Composite Reliability >0.6 for exploratory research or >0.7 for developed research.*

***Cronbachs Alpha is included for reference. Composite reliability is prefered over Conbach's Alpha for PLS-SEM.*

Refer: Hair J. F. 2011, PLS-SEM: Indeed a Silver Bullet

Latent variable correlations compared with √(AVE), i.e. check √(AVE)> factor loading, Bold=√(AVE)

Av R^2	*Av Com.*
0.37	*0.72*
Gof =	*0.51*

Goodness of fit Calculation: Gof = SQRT((Avg R^2)(Avg Com.))*

Gof > 0.31 recommended

Figure 150 SEM K.3 quality overview and Fornell - Larcker criterion

SEM K.3 Resultant Model

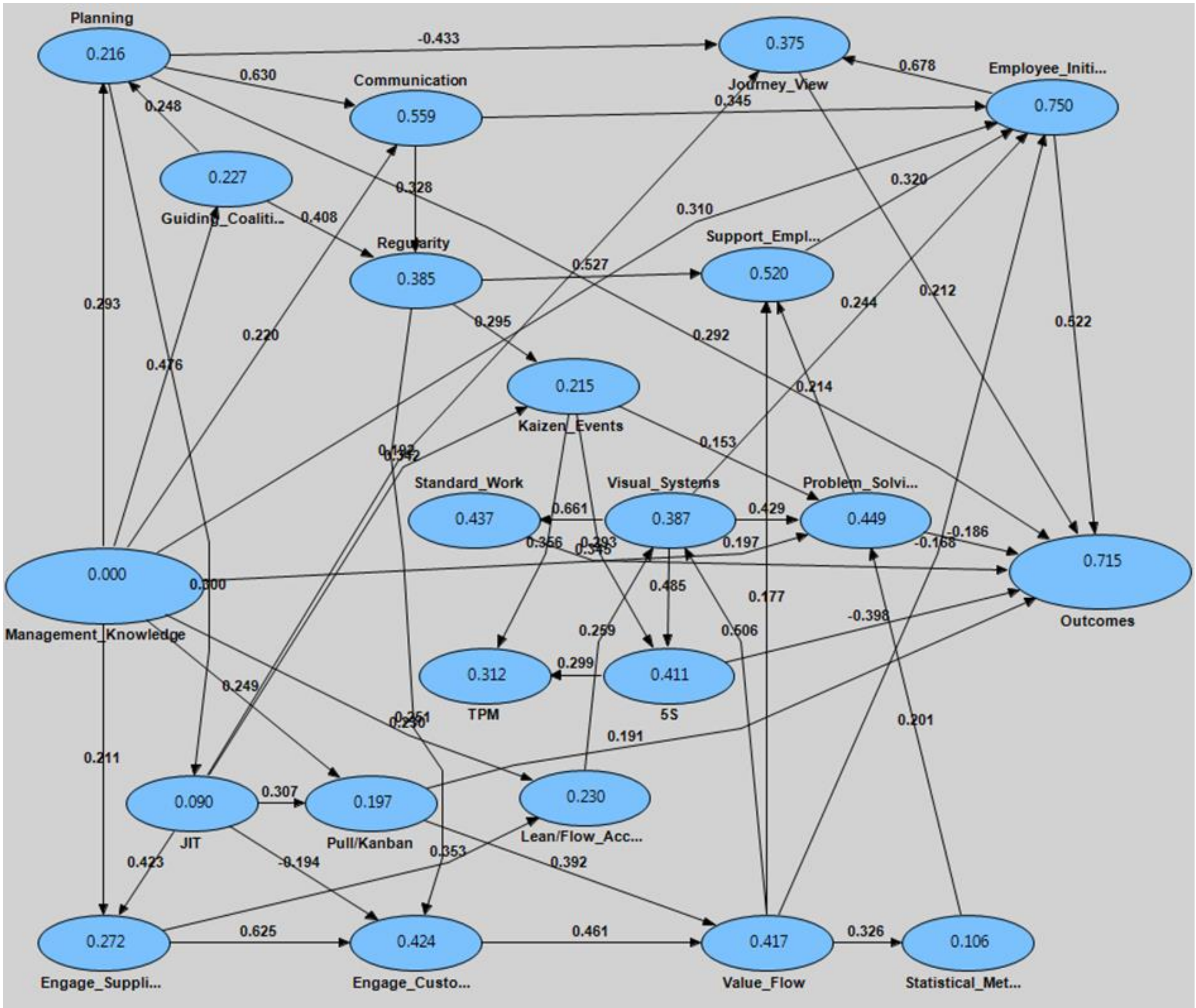

Figure 151 SEM K.3 resultant model of the Lean Knowledge-Based View for the small business case (11-100 employees, 80 lean and lean six sigma cases, 90%+ complete, all paths significant with p<0.06, bootstrapped 5000 times, individual sign changes allowed).

Negative relationships and p>0.01 highlighted	Original Sample (β)	Sample Mean	Standard Deviation	Standard Error	T Statistics	p -value (Significance)
Management Knowledge->Communication	0.22	0.23	0.08	0.08	2.76	0.00711
Management Knowledge->Employee Initiatives (Enabled)	0.31	0.31	0.08	0.08	4.03	0.00013
Management Knowledge->Engage Suppliers	0.21	0.21	0.10	0.10	2.18	0.03216
Management Knowledge->Guiding Coalition	0.48	0.47	0.10	0.10	4.91	0.00000
Management Knowledge->Lean/Flow Accounting	0.23	0.23	0.10	0.10	2.36	0.02097
Management Knowledge->Planning	0.29	0.30	0.10	0.10	2.83	0.00597
Management Knowledge->Problem Solving (Simple)	0.20	0.20	0.09	0.09	2.14	0.03569
Management Knowledge->Pull/Kanban	0.25	0.26	0.10	0.10	2.45	0.01645

Figure 152 SEM K.3 direct effects of management Knowledge

Negative relationships and p>0.01 highlighted	Original Sample (β)	Sample Mean	Standard Deviation	Standard Error	T Statistics	p -value (Significance)
Kaizen Events->Problem Solving (Simple)	0.15	0.16	0.08	0.08	1.94	0.05555
JIT->Journey View	0.19	0.19	0.09	0.09	2.04	0.04437
JIT->Engage Customers	-0.19	-0.20	0.09	0.09	2.05	0.04381
Value Flow->Support Employees	0.18	0.19	0.08	0.08	2.11	0.03836
Management Knowledge->Problem Solving (Simple)	0.20	0.20	0.09	0.09	2.14	0.03569

Figure 153 SEM K.3 five least significant paths

Negative relationships and p>0.01 highlighted	Original Sample (β)	Sample Mean	Standard Deviation	Standard Error	T Statistics	p -value (Significance)
Employee Initiatives (Enabled)->Journey View	0.68	0.68	0.09	0.09	7.27	0.00000
Visual Systems->Standard Work	0.66	0.66	0.07	0.07	9.40	0.00000
Planning->Communication	0.63	0.63	0.06	0.06	9.90	0.00000
Engage Suppliers->Engage Customers	0.62	0.62	0.10	0.10	6.02	0.00000
Regularity->Support Employees	0.53	0.52	0.07	0.07	7.31	0.00000
Employee Initiatives (Enabled)->Outcomes	0.52	0.52	0.08	0.08	6.91	0.00000
Value Flow->Visual Systems	0.51	0.51	0.09	0.09	5.88	0.00000
Visual Systems->5S	0.48	0.49	0.10	0.10	4.71	0.00001
Management Knowledge->Guiding Coalition	0.48	0.47	0.10	0.10	4.91	0.00000
Engage Customers->Value Flow	0.46	0.46	0.07	0.07	6.88	0.00000

Figure 154 SEM K.3 largest path coefficients.

Negative relationships and p>0.01 highlighted	Original Sample (β)	Sample Mean	Standard Deviation	Standard Error	T Statistics	p -value (Significance)
Employee Initiatives (Enabled)->Outcomes	0.52	0.52	0.08	0.08	6.91	0.00000
Standard Work->Outcomes	0.35	0.33	0.08	0.08	4.09	0.00010
Planning->Outcomes	0.29	0.29	0.07	0.07	3.93	0.00018
Journey View->Outcomes	0.21	0.21	0.07	0.07	2.83	0.00590
Pull/Kanban->Outcomes	0.19	0.20	0.08	0.08	2.54	0.01307
Problem Solving (Simple)->Outcomes	-0.19	-0.19	0.07	0.07	2.73	0.00792

Figure 155 SEM K.3 direct effects on Outcomes.

Negative relationships and p>0.01 highlighted	Original Sample (β)	Sample Mean	Standard Deviation	Standard Error	T Statistics	p -value (Significance)
Planning->Journey View	-0.43	-0.44	0.10	0.10	4.38	0.00004
5S->Outcomes	-0.40	-0.40	0.10	0.10	4.07	0.00011
JIT->Engage Customers	-0.19	-0.20	0.09	0.09	2.05	0.04381
Problem Solving (Simple)->Outcomes	-0.19	-0.19	0.07	0.07	2.73	0.00792
Value Flow->Employee Initiatives (Enabled)	-0.17	-0.16	0.07	0.07	2.55	0.01272

Figure 156 SEM K.3 negative relationships observed.

SEM K.3 Outcomes

Given the explorative nature, the small business model very strongly explained variance in Outcomes with R^2 of 0.72 achieved. The following results were significant to this work.

- This was the strongest model in explaining Outcomes (R^2 =0.72).

- The strongest direct relationship with Outcomes was from Employee Initiatives (enabled) (β=0.52).
- Standard Work had the second strongest direct relationship with Outcomes. The path coefficient (β=0.35) was 67% of that for Employee Initiatives-> Outcomes.
- Standard Work was strongly related to Visual Systems (β=0.66).
- Weaker direct relationships with Outcomes were Planning (β=0.29), Journey View (β=0.21) and Pull/Kanban (β=0.19)
- The strongest chain of causality was from Management Knowledge through Planning, Communication to Employee initiatives.
- Additional strong paths occur through Guiding Coalition to Regularity through Support Employees to Employee Initiatives (enabled).
- The key components of implementation were explained directly or indirectly by Management Knowledge.

Particularly interesting relationships were observed through Journey View.

- Journey View acted as a partial mediator between Employee initiatives and Outcomes.
- A particularly strong relationship (0.69) was observed between Employee Initiatives and Journey View.
- Journey View had a significant direct negative path from planning (-0.43).
- This indicates being overly relaxed in the approach to lean. Although recognising implementation takes time is appropriate, taking that as an excuse to avoid planning and building momentum is not appropriate. This attitude was observed in the case studies also.

Other negative paths were found.

- 5S to Outcomes, β=-0.40, was a strong negative correlation considering the other positive effects of 5S.
- Also JIT to Engage Customers (-0.23), Problem Solving to Outcomes (-0.19) and Value Flow to Employee Initiatives were significant negative paths.
- The above negative paths show an over emphasis of the methods without considering the critical success factors; i.e. customer engagement and staff enablement.

In general:

- The advanced processes, represented strongly by Pull/Kanban, are mediated to Outcomes by the application of simple techniques (represented by TPM, 5S, Visual Systems and Standard Work). The effects of all these methods are mediated to Outcomes through Regularity, the Support for Employees, and Employee Initiatives. Developing Employee Initiatives was strongly related to the Journey View, a partial mediator to Outcomes.

Again, the SEM showed that the effects of leadership and enabling employees on outcomes were significant by themselves, the strongest in each model. These were also mediators between the lean methods and success.

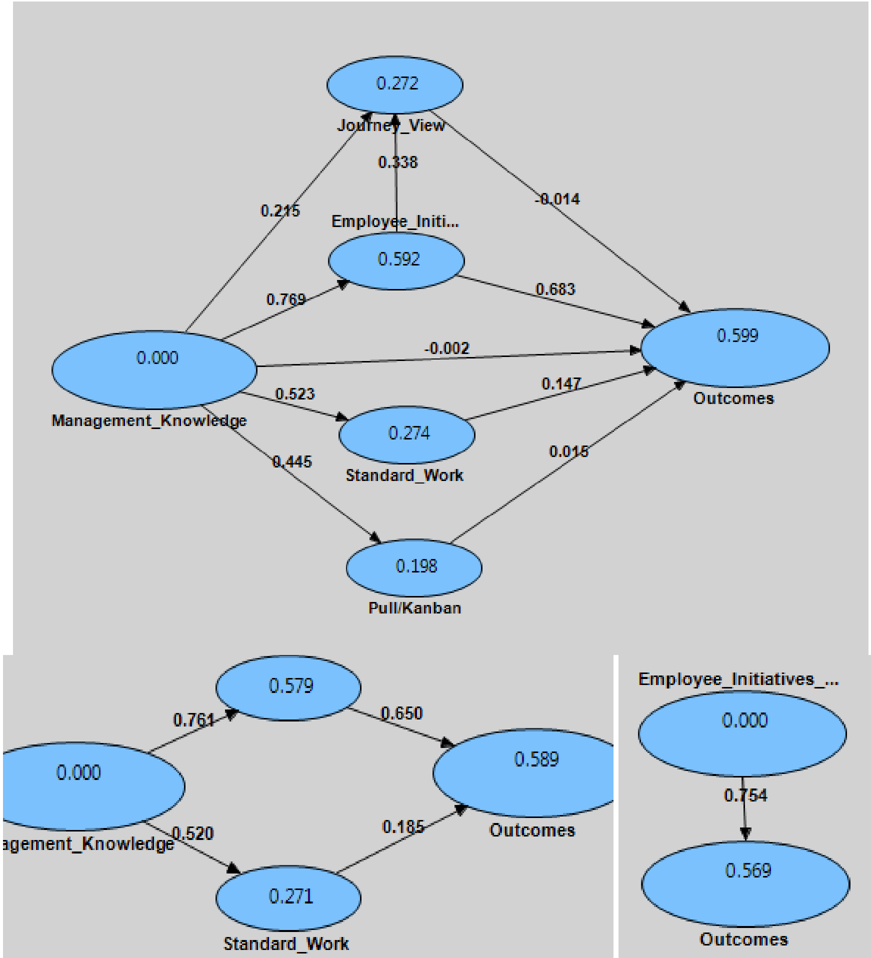

Figure 157 SEM K.3 simplified representation: Management Knowledge and Employee Initiatives (enabled) acting on Outcomes. Insignificant paths (β<0.07) were removed.

The significant effects of leadership enabling employee initiatives are represented in the simplified SEMs in Figure 157. These SEMs show:

> 57% of variance of Outcomes was explained by Employee Initiatives acting on Outcomes (67% of the 79% variance explained in the full SEM K.3).

The majority of the variance in Outcomes (explained by SEM K.3) was explained by management knowledge expressed through the enabling of employee initiatives.

8.3.4 SEM K.4 Low-Variety High-Volume Manufacture

Categorical analysis of the low-variety high-volume scenario gave 96 cases (data, 90%+ complete). This sample size was borderline by the 10 x paths rule (9 paths were found significant to Outcomes). Although borderline, this was sufficient for the explorative nature of this work. But because of this, a lower acceptance level, $\alpha=0.1$ was set.

Although $\alpha=0.1$ shows weaker correlation it is acceptable as guided by Hair et al. (2011). In paths were weaker in this model due to the relatively small data set. The 0.1 significance level proved to be appropriate leaving only significant causality in the model without multiple spurious paths. Ultimately, only five paths were retained with $p>0.06$.

Explorative Modelling

The causality between Statistical Methods and Information Systems was unclear, the path coefficients were similar independent of the causal direction ($\beta=2.3$ and 2.6), neither construct overpowered the other as a mediator. It is assumed that the use of statistical methods is prominent where information systems made data available. Conversely, the desire to carry out statistical analysis is a driver for installing more advanced information systems.

No constructs were removed during the analysis.

SEM K.4 Model Validation

The following table is an overview of model quality, see questionnaire One for details of interpretation (p. 182).

Quality Overview | **Fornell-Larcker Criterion (Fornell & Larcker,1981)**

	AVE	Composite Reliability	Cronbachs Alpha	Redundancy	R Square	Communality	5S	Communication	Employee Initiatives	Engage Customers	Engage Suppliers	Guiding Coalition	Information Systems	JIT	Journey View	Kaizen Events	Lean/Flow Accounting	Management Knowledge	Outcomes	Planning	Problem Solving (Simple)	Pull/Kanban	Regularity	Resource	Satistical Methods	Standard Work	Support Employees	TPM	Value Flow	Visual Systems
Significancecriteria	*>0.5*	*>0.6**	*>0.7***		*>0.1*																									
Minimum	*0.76*	*0.91*	*0.84*		*0.17*	*0.76*																								
5S	1.00	1.00	1.00	0.15	0.35		**N/A**																							
Communication	0.85	0.95	0.92	0.20	0.47	0.85	0.10	**0.92**																						
Employee Initiatives	0.76	0.91	0.84	0.26	0.64	0.76	0.35	0.67	**0.87**																					
Engage Customers	1.00	1.00	1.00	0.55	0.60		-0.04	0.44	0.33	**N/A**																				
Engage Suppliers	1.00	1.00	1.00	0.35	0.41		0.16	0.40	0.41	0.75	**N/A**																			
Guiding Coalition	1.00	1.00	1.00	-0.13	0.29		0.41	0.23	0.52	0.11	0.25	**N/A**																		
Information Systems	1.00	1.00	1.00	0.17	0.17		0.19	0.16	0.23	0.40	0.41	0.30	**N/A**																	
JIT	1.00	1.00	1.00	0.22	0.26		0.24	0.39	0.44	0.51	0.61	0.22	0.33	**N/A**																
Journey View	1.00	1.00	1.00	0.30	0.41		0.08	0.31	0.55	0.19	0.32	0.28	0.04	0.27	**N/A**															
Kaizen Events	1.00	1.00	1.00	0.15	0.31		0.42	0.39	0.23	0.00	0.05	0.21	0.20	0.22	0.05	**N/A**														
Lean/Flow Accounting	1.00	1.00	1.00	0.25	0.25		0.08	0.32	0.44	0.34	0.45	0.12	0.49	0.33	0.25	0.00	**N/A**													
Management Knowledge	0.70	0.88	0.79		1.00	0.70	0.27	0.58	0.75	0.42	0.48	0.39	0.30	0.49	0.53	0.20	0.50	**0.84**												
Outcomes	0.82	0.93	0.89	0.14	0.64	0.82	0.11	0.53	0.65	0.44	0.41	0.28	0.10	0.46	0.43	0.11	0.40	0.64	**0.90**											
Planning	1.00	1.00	1.00	0.45	0.45		0.19	0.66	0.73	0.38	0.44	0.38	0.28	0.44	0.25	0.17	0.35	0.67	0.59	**N/A**										
Problem Solving (Simple)	1.00	1.00	1.00	0.09	0.46		0.34	0.21	0.46	0.21	0.33	0.34	0.16	0.49	0.50	0.23	0.23	0.54	0.41	0.31	**N/A**									
Pull/Kanban	0.83	0.91	0.80	0.36	0.48	0.83	0.25	0.36	0.25	0.34	0.45	0.06	0.26	0.67	0.15	0.36	0.29	0.39	0.30	0.36	0.33	**0.91**								
Regularity	1.00	1.00	1.00	0.21	0.47		0.30	0.48	0.38	0.23	0.28	0.37	0.10	0.27	0.14	0.38	0.07	0.33	0.27	0.47	0.22	0.18	**N/A**							
Resource	0.74	0.85	0.65	0.20	0.28	0.74	0.08	0.34	0.40	0.58	0.54	0.13	0.26	0.53	0.33	-0.08	0.37	0.38	0.40	0.37	0.23	0.21	0.36	**0.86**						
Satistical Methods	1.00	1.00	1.00	0.11	0.21		0.30	0.12	0.09	0.24	0.32	0.32	0.34	0.36	0.14	0.16	0.18	0.25	0.19	0.12	0.27	0.39	0.18	0.24	**N/A**					
Standard Work	1.00	1.00	1.00	0.31	0.40		0.34	0.28	0.48	0.21	0.27	0.34	0.22	0.38	0.36	0.29	0.38	0.58	0.38	0.30	0.40	0.27	0.33	0.29	0.18	**N/A**				
Support Employees	0.75	0.86	0.66	0.29	0.64	0.75	0.29	0.62	0.69	0.43	0.44	0.40	0.32	0.49	0.30	0.37	0.26	0.56	0.61	0.53	0.38	0.23	0.51	0.42	0.21	0.33	**0.86**			
TPM	1.00	1.00	1.00	0.17	0.41		0.49	0.38	0.38	0.24	0.36	0.31	0.26	0.39	0.27	0.42	0.40	0.48	0.25	0.39	0.46	0.45	0.55	0.30	0.31	0.50	0.35	**N/A**		
Value Flow	0.54	0.78	0.57	0.17	0.44	0.54	0.24	0.58	0.51	0.34	0.38	0.27	0.25	0.61	0.32	0.48	0.33	0.47	0.45	0.46	0.40	0.60	0.31	0.24	0.33	0.30	0.56	0.43	**0.74**	
Visual Systems	1.00	1.00	1.00	0.25	0.59		0.52	0.23	0.47	0.21	0.40	0.21	0.01	0.38	0.47	0.24	0.23	0.62	0.46	0.27	0.61	0.42	0.31	0.26	0.26	0.57	0.41	0.55	0.38	**N/A**

**Composite Reliability >0.6 for exploratory research or >0.7 for developed research.*

***Cronbachs Alpha is included for reference. Composite reliability is prefered over Conbach's Alpha for PLS-SEM. Refer: Hair J. F. 2011, PLS-SEM: Indeed a Silver Bullet*

Av R^2	Av Com.
0.44	*0.75*
Gof =	*0.58*

Goodness of fit Calculation: *Gof = SQRT((Avg R^2)*(Avg Com.))*
Gof > 0.31 recommended

Latent variable correlations compared with √(AVE), i.e. check √(AVE)> factor loading, Bold=√(AVE)

Figure 158 SEM K.4 quality overview and Fornell - Larcker criterion

SEM K.4 Resultant Model

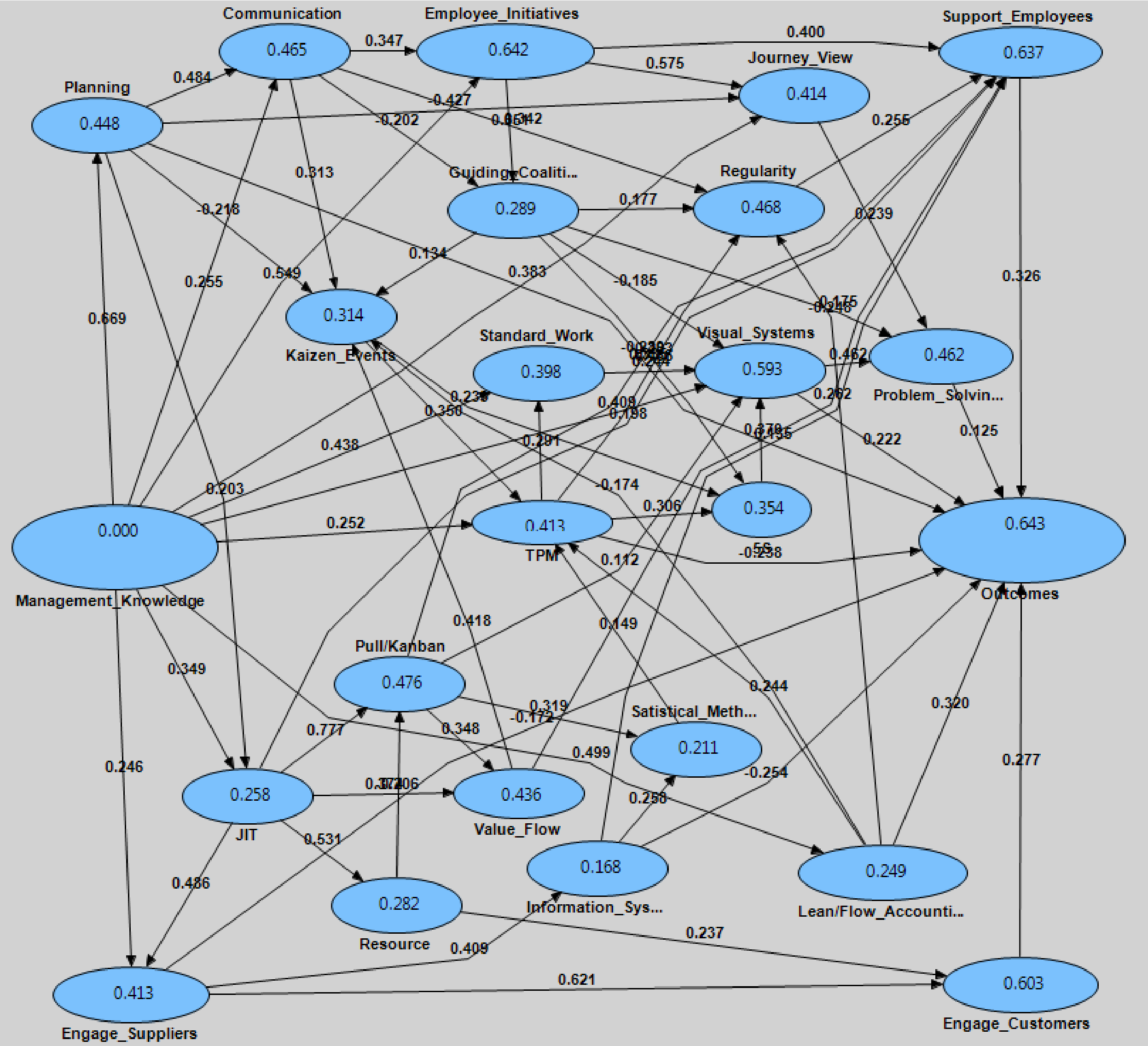

Figure 159 SEM K.4 resultant model of the Lean Knowledge-Based View for the low-variety high-volume case (96 lean and lean six sigma cases, 90%+ complete, all paths significant with p<0.05, except as shown in Figure 161, bootstrapped 5000 times, individual sign changes allowed).

Negative relationships and p>0.01 highlighted	Original Sample (β)	Sample Mean	Standard Deviation	Standard Error	T Statistics	p -value (Significance)
Management Knowledge->Communication	0.26	0.26	0.11	0.11	2.25	0.02676
Management Knowledge->Employee Initiatives	0.55	0.54	0.08	0.08	7.04	0.00000
Management Knowledge->Engage Suppliers	0.25	0.25	0.08	0.08	3.07	0.00282
Management Knowledge->JIT	0.35	0.35	0.10	0.10	3.48	0.00076
Management Knowledge->Journey View	0.38	0.38	0.12	0.12	3.18	0.00199
Management Knowledge->Lean/Flow Accounting	0.50	0.50	0.07	0.07	7.45	0.00000
Management Knowledge->Planning	0.67	0.67	0.08	0.08	8.80	0.00000
Management Knowledge->Standard Work	0.44	0.43	0.10	0.10	4.30	0.00004
Management Knowledge->TPM	0.25	0.27	0.11	0.11	2.32	0.02236
Management Knowledge->Visual Systems	0.41	0.41	0.09	0.09	4.57	0.00001

Figure 160 SEM K.4 direct effects of Management Knowledge

Negative relationships and p>0.01 highlighted	Original Sample (β)	Sample Mean	Standard Deviation	Standard Error	T Statistics	p -value (Significance)
Guiding Coalition->Kaizen Events	0.13	0.14	0.08	0.08	1.59	0.11540
Problem Solving (Simple)->Outcomes	0.12	0.13	0.08	0.08	1.64	0.10339
Satistical Methods->TPM	0.15	0.15	0.09	0.09	1.67	0.09902
Lean/Flow Accounting->Kaizen Events	-0.17	-0.18	0.09	0.09	1.83	0.06970
Pull/Kanban->Visual Systems	0.11	0.12	0.06	0.06	1.85	0.06708
Guiding Coalition->Regularity	0.18	0.18	0.09	0.09	1.89	0.06219
Planning->Kaizen Events	-0.22	-0.22	0.11	0.11	1.95	0.05450
Engage Suppliers->Outcomes	-0.17	-0.17	0.09	0.09	1.98	0.05037
Resource->Pull/Kanban	-0.21	-0.20	0.10	0.10	2.01	0.04775
Guiding Coalition->Problem Solving (Simple)	0.17	0.18	0.09	0.09	2.04	0.04435

Figure 161 SEM K.4 least significant paths

Negative relationships and p>0.01 highlighted	Original Sample (β)	Sample Mean	Standard Deviation	Standard Error	T Statistics	p -value (Significance)
JIT->Pull/Kanban	0.78	0.78	0.07	0.07	10.85	0.00000
Management Knowledge->Planning	0.67	0.67	0.08	0.08	8.80	0.00000
Employee Initiatives->Guiding Coalition	0.65	0.65	0.11	0.11	6.00	0.00000
Engage Suppliers->Engage Customers	0.62	0.62	0.08	0.08	7.79	0.00000
Employee Initiatives->Journey View	0.58	0.57	0.12	0.12	4.98	0.00000
Management Knowledge->Employee Initiatives	0.55	0.54	0.08	0.08	7.04	0.00000
JIT->Resource	0.53	0.53	0.07	0.07	7.29	0.00000
Management Knowledge->Lean/Flow Accounting	0.50	0.50	0.07	0.07	7.45	0.00000

Figure 162 SEM K.4 largest path coefficients.

Negative relationships and p>0.01 highlighted	Original Sample (β)	Sample Mean	Standard Deviation	Standard Error	T Statistics	p -value (Significance)
Planning->Outcomes	0.33	0.32	0.10	0.10	3.28	0.00148
Support Employees->Outcomes	0.33	0.35	0.09	0.09	3.67	0.00041
Lean/Flow Accounting->Outcomes	0.32	0.33	0.08	0.08	4.10	0.00009
Engage Customers->Outcomes	0.28	0.27	0.09	0.09	3.02	0.00324
Visual Systems->Outcomes	0.22	0.22	0.10	0.10	2.15	0.03436
Problem Solving (Simple)->Outcomes	0.12	0.13	0.08	0.08	1.64	0.10339
Engage Suppliers->Outcomes	-0.17	-0.17	0.09	0.09	1.98	0.05037
TPM->Outcomes	-0.24	-0.24	0.10	0.10	2.49	0.01470
Information Systems->Outcomes	-0.25	-0.26	0.09	0.09	2.92	0.00439

Figure 163 SEM K.4 direct effects on Outcomes.

Negative relationships and p>0.01 highlighted	Original Sample (β)	Sample Mean	Standard Deviation	Standard Error	T Statistics	p -value (Significance)
Engage Suppliers->Outcomes	-0.17	-0.17	0.09	0.09	1.98	0.05037
Lean/Flow Accounting->Kaizen Events	-0.17	-0.18	0.09	0.09	1.83	0.06970
Guiding Coalition->Visual Systems	-0.19	-0.18	0.07	0.07	2.61	0.01063
Communication->Guiding Coalition	-0.20	-0.20	0.09	0.09	2.29	0.02403
Resource->Pull/Kanban	-0.21	-0.20	0.10	0.10	2.01	0.04775
Planning->Kaizen Events	-0.22	-0.22	0.11	0.11	1.95	0.05450
TPM->Outcomes	-0.24	-0.24	0.10	0.10	2.49	0.01470
Pull/Kanban->Support Employees	-0.24	-0.24	0.09	0.09	2.70	0.00827
Lean/Flow Accounting->Regularity	-0.25	-0.24	0.09	0.09	2.79	0.00644
Information Systems->Outcomes	-0.25	-0.26	0.09	0.09	2.92	0.00439
Planning->Journey View	-0.43	-0.42	0.12	0.12	3.66	0.00041

Figure 164 SEM K.4 negative relationships observed.

SEM K.4 Outcomes

Considering the explorative nature, the low-variation high-volume model very strongly explains Outcomes; the variance in Outcomes (R^2) was 0.64. The following results were significant to this work.

In reviewing the model it was clear that lean processes play a more significant role in the low-variety high-volume manufacture than other cases (as was foreshadowed by HB.7, p. 243).

- The strongest direct relationship with Outcomes was not from Employee Initiatives as all other cases.
- Although Employee initiatives played a significant role, Support Employees to Outcomes was the most significant mediator to success.
- Support Employees to Outcomes and Planning to Outcomes had the same path coefficient β=0.33.
- Support Employees to Outcomes was more significant by p value (p=0.0000[153] cf. 0.0015).
- Higher path coefficients were observed overall including direct relationships with Outcomes. The lean systems were more significant to success than they were in other categories.

[153] 0.00004

- Other strong direct paths to Outcomes were Lean/Flow Accounting to Outcomes, β=0.32 and Engage Customers to Outcomes, β=0.28.
- Visual Systems to Outcomes was weaker at 0.22 and Problem Solving to Outcomes was much weaker at 0.12. This path could have been removed but is interesting to show that, although negative in other models, it was positive here. There is no evidence that simple problem solving is overdone in the low variety high volume scenario.
- A particularly strong relationship (0.58) was observed between Employee Initiatives and Journey View but (as the small business model) Journey View had the strongest negative path, -0.43 from planning.
- This indicates being overly relaxed in the approach to lean (as in the small business case). As stated there, *recognising implementation takes time is appropriate, taking that as an excuse to avoid planning and building momentum is not appropriate*. These attitudes were seen in the industry case study component.
- TPM[154] appears to be overdone with a negative direct correlation to Outcomes; although a positive indirect relationship was found through simple methods. This was the strongest negative path observed (β=-0.24) in this model.
- A negative relationship between Engaging Suppliers and Outcomes (β=-0.17) bypassed Engaging Customers. This indicates a JIT implementation[155] that managed the supply and implementation of a system without engaging customers.
- Over focus on information systems (as opposed to basic pull systems) gave a negative relationship to Outcomes (β=-0.25).
- Lean/Flow accounting showed a β=-0.25 path to Regularity which may represent Accounting taking too strong a lead and becoming obstructive. This needs further investigation.
- Pull/Kanban to Support Employees was an equally strong negative path (β=-0.24). This also indicates an overemphasis of methods without proper leadership. The positive benefits of Pull/Kanban systems were seen through understanding Value/Flow (defining value, mapping the value stream).
- Other negative relationships (Figure 164) indicate further competing priorities. These were: an elite guiding coalition versus communication with all staff (β=-0.20) and the use of visual systems (β=-

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[154] A direct negative relationship between statistical methods and employee initiatives was observed. This was overpowered by other relationships and became insignificant in the model (β=-0.1) but is apparently part of the negative effects seen from TPM (with which Statistical methods was related).

[155] See strong path from JIT to Engage Suppliers.

0.19); resources (technology emphasis)[156] versus simple pull systems (β=-0.21); and a focus on Kaizen Events[157] versus the positive effects of management planning (β=-0.22) and use of Lean/Flow Accounting (β=-0.17).

- The many negative relationships show how important it is for leadership to understand, and be involved in, the lean implementation process, managing the risks.

In this low-variety high-volume model there were many strong lines of causality. However the strongest lines of causality still represent leadership and enabling development (through employee support).

- The strongest chain of causality was from Management Knowledge through Planning to Outcomes directly and as mediated by Communication and Employee Initiatives through Support for Employees.
- The key components of implementation were either explained directly or indirectly by Management Knowledge.

An interesting insight was Support Employees switching roles with Employee Initiatives as the major mediator (comparison with other SEM K).

- Employee Initiatives was still significant in the model, but did not have a direct relationship with Outcomes. It was not the main mediator for Outcomes as it was in the other models.
- Support for Employees was more important for success in the low-variation high-volume scenario. Employee Initiatives contributed to Outcomes through it.
- The advanced lean process techniques are particularly beneficial in the low-variation high-volume scenario but their success is reliant on supporting employees in the change process (see path from JIT through support for employees).

Although lean processes were more important in low-variation high-volume manufacture, the effects on Outcomes of Leadership and Enabling were still significant themselves and were also the overriding mediators for the methods and processes. Planning, Lean/Flow Accounting and JIT through engaging the extended value stream (Engage Suppliers and Engage Customers) were particularly beneficial in this case. Effects on Outcomes were similar for these as for the factors of enabling development (e.g. support for employees and their initiative). As previous models, Management Knowledge significantly explained the key components. See simplified representations in Figure 165.

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[156] This is not the same as information systems (Technology Capability and use of Information Systems did not relate or load well in the same construct).

[157] An overuse of Kaizen events or certain methods indicates a tool and consultant approach to lean.

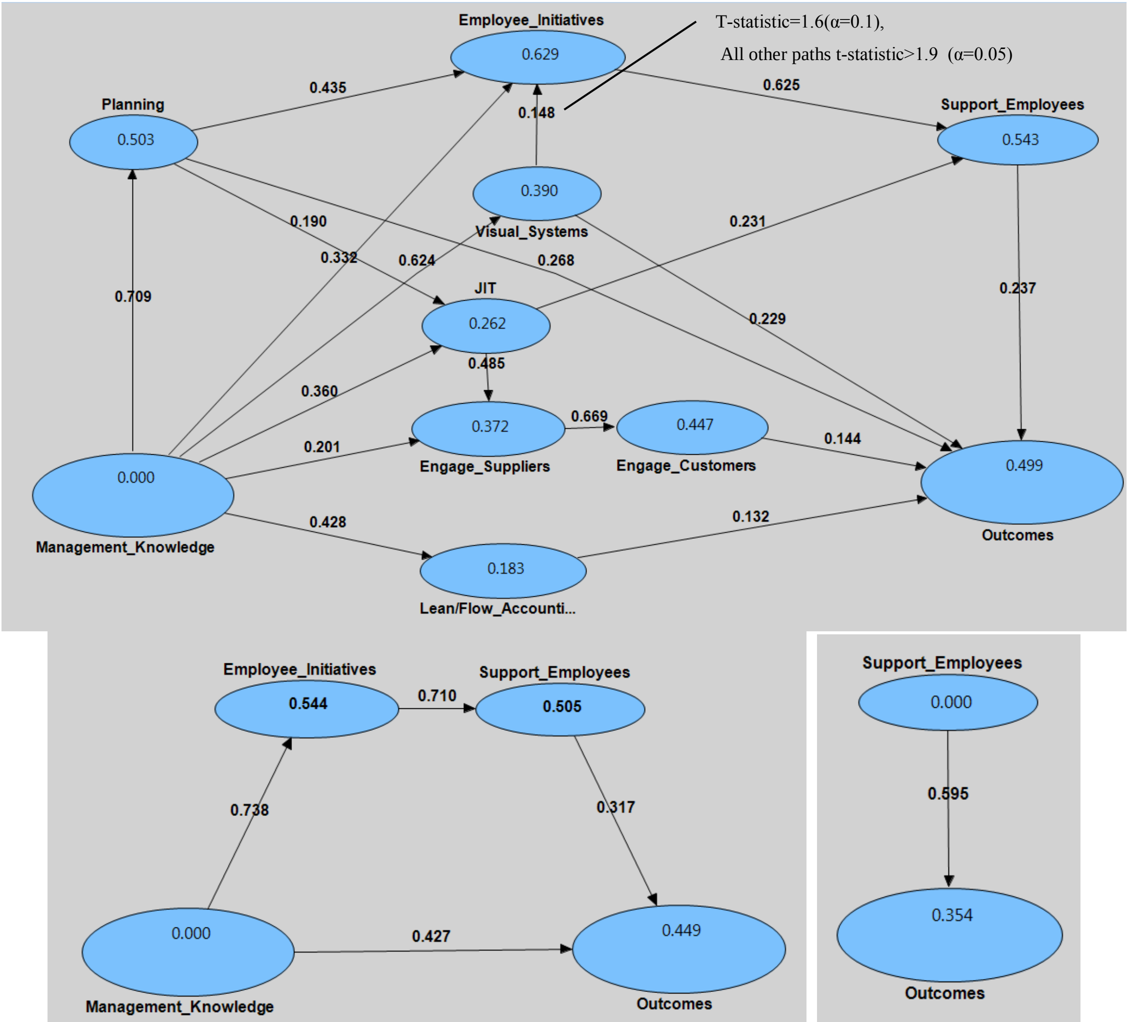

Figure 165 SEM K.4 simplified representations: Management Knowledge, lean systems and Support Employees acting on Outcomes (in the top SEM Management Knowledge to Outcomes was insignificant, p>0.1).

The significant effects of leadership, supporting employees, and significant lean components are represented in the simplified SEMs, Figure 165. These SEMs show:

- 35% of variance of Outcomes was explained by the relationship between Support Employees and Outcomes (55% of the 64% variance explained in full SEM K.4)
- 69% was explained by Management Knowledge with Support Employees (significant partial mediation).

The majority of the variance in Outcomes, explained by SEM K.4, can be explained by management knowledge, expressed through the leadership and enabling aspects. Leadership and enabling development were represented by the construct Support Employees, Figure 165.

8.3.5 SEM K.5 High-Variety Low-Volume

The high-variety low-volume case (all lean and lean six sigma data, 90%+ complete) contained 86 cases. By the ten times rule the sample size was suitable. The maximum number of paths to any construct was four.

This suitable sample size meant a significance level α=0.05 was used.[158] This level resulted in an adequately simple structure and considerable β values.

Indicators and Constructs Removed

For the high-variety low-volume case, Construct indicator modifications were required to arrive at a satisfactory solution. Explorative analysis showed that the model was very sensitive to measures of leadership and enablement. Testing by Fornell – Larker criterion showed discriminant validity was acceptable but indicator cross loading and latent variable correlations were still high. A more discriminant solution was sought.

V057 Involved all staff was removed from the Employee Initiative construct to reduce cross loadings.

An alternative to this was considered, that was removing V040 Sustained Implementation from Outcomes. This would have reduced cross loadings, but specific insights, including negative correlations to Outcomes, would have been lost.

Additionally the Journey View construct was removed to simplify modelling of causality.

The journey view is strongly relevant in situations highly focused on employee enablement through leadership. It confounded other causality as an overriding view and was removed. Future constructs could be developed to fully represent these concepts.

In the Resources Construct its indicators Staff Capability and Technology Capability loaded unevenly, 0.91 and 0.74 respectively. Using these measures for single indicator constructs showed some interesting relationships (see p. 437), but they were not observed to contribute to the overall model significantly. They were removed. Information Systems was weakly described (16%) and was not related back to the model; it was also removed.

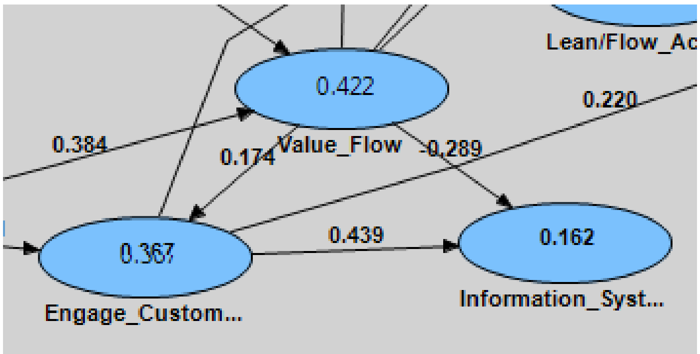

Figure 166 SEM K.5 relationships to information systems (removed from model).

SEM K.5 Model Validation

The following table is an overview of model quality, see questionnaire One for details of interpretation (p. 182).

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[158] Some borderline secondary paths were removed during exploration meaning essentially an α of 0.025. These paths are recorded in Figure 170.

Quality Overview **Fornell-Larcker Criterion (Fornell & Larcker,1981)**

	AVE	Composite Reliability	Cronbachs Alpha	Redundancy	R Square	Communality	5S	Communication	Employee Initiatives (Enabled)	Engage Customers	Engage Suppliers	Guiding Coalition	JIT	Kaizen Events	Lean/Flow Accounting	Management Knowledge	Outcomes	Planning	Problem Solving (Simple)	Pull/Kanban	Regularity	Standard Work	Statistical Methods	Support Employees	TPM	Value Flow	Visual Systems
Significancecriteria	*>0.5*	*>0.6**	*>0.7***		*>0.1*																						
Minimum	*0.75*	*0.86*	*0.67*		*0.29*	*0.75*																					
5S	1.00	1.00	1.00	0.13	0.44		**N/A**																				
Communication	0.81	0.95	0.92	0.20	0.50	0.81	0.33	**0.90**																			
Employee Initiatives (Enabled)	0.75	0.86	0.67	0.23	0.68	0.75	0.42	0.66	**0.87**																		
Engage Customers	1.00	1.00	1.00	0.35	0.35		0.11	0.47	0.28	**N/A**																	
Engage Suppliers	1.00	1.00	1.00	0.39	0.39		0.30	0.62	0.47	0.59	**N/A**																
Guiding Coalition	1.00	1.00	1.00	0.13	0.29		0.35	0.37	0.37	0.13	0.30	**N/A**															
JIT	1.00	1.00	1.00	0.25	0.33		0.40	0.51	0.51	0.22	0.56	0.42	**N/A**														
Kaizen Events	1.00	1.00	1.00	0.36	0.41		0.44	0.36	0.50	0.16	0.22	0.31	0.47	**N/A**													
Lean/Flow Accounting	1.00	1.00	1.00	0.28	0.35		0.09	0.54	0.37	0.24	0.45	0.06	0.37	0.33	**N/A**												
Management Knowledge	0.70	0.87	0.79			0.70	0.36	0.56	0.66	0.30	0.46	0.28	0.52	0.43	0.45	**0.84**											
Outcomes	0.69	0.87	0.78	0.38	0.66	0.69	0.27	0.64	0.75	0.40	0.54	0.39	0.45	0.39	0.47	0.55	**0.83**										
Planning	1.00	1.00	1.00	0.29	1.00		0.17	0.67	0.58	0.32	0.52	0.32	0.49	0.29	0.49	0.54	0.47	**N/A**									
Problem Solving (Simple)	0.84	0.91	0.81	0.18	0.64	0.84	0.57	0.38	0.58	0.41	0.37	0.32	0.47	0.68	0.28	0.46	0.39	0.35	**0.91**								
Pull/Kanban	0.84	0.91	0.81	0.25	0.38	0.84	0.42	0.44	0.62	0.08	0.42	0.42	0.57	0.61	0.46	0.50	0.55	0.46	0.54	**0.92**							
Regularity	0.71	0.83	0.60	0.26	0.54	0.71	0.47	0.54	0.62	0.28	0.29	0.62	0.54	0.56	0.27	0.52	0.52	0.51	0.56	0.48	**0.84**						
Standard Work	1.00	1.00	1.00	0.25	0.31		0.35	0.47	0.55	0.36	0.52	0.48	0.50	0.37	0.13	0.41	0.53	0.47	0.39	0.47	0.51	**N/A**					
Statistical Methods	1.00	1.00	1.00	0.14	0.25		0.23	0.32	0.28	0.23	0.33	0.30	0.24	0.34	0.41	0.32	0.24	0.50	0.36	0.45	0.41	0.36	**N/A**				
Support Employees	0.72	0.84	0.61	0.18	0.61	0.72	0.38	0.61	0.77	0.38	0.45	0.52	0.45	0.56	0.36	0.59	0.69	0.46	0.56	0.56	0.70	0.55	0.39	**0.85**			
TPM	1.00	1.00	1.00	0.32	0.32		0.45	0.44	0.39	0.28	0.27	0.30	0.28	0.56	0.38	0.35	0.34	0.26	0.56	0.47	0.31	0.20	0.35	0.51	**N/A**		
Value Flow	0.76	0.86	0.69	0.14	0.49	0.76	0.41	0.57	0.52	0.45	0.56	0.28	0.47	0.49	0.46	0.55	0.42	0.55	0.65	0.53	0.50	0.39	0.38	0.54	0.39	**0.87**	
Visual Systems	1.00	1.00	1.00	0.23	0.49		0.58	0.53	0.61	0.31	0.40	0.31	0.45	0.48	0.27	0.55	0.47	0.39	0.59	0.46	0.46	0.41	0.15	0.54	0.46	0.55	**N/A**

**Composite Reliability >0.6 for exploratory research or >0.7 for developed research.*

***Cronbachs Alpha is included for reference. Composite reliability is prefered over Conbach's Alpha for PLS-SEM. Refer: Hair J. F. 2011, PLS-SEM: Indeed a Silver Bullet*

Latent variable correlations compared with √(AVE), i.e. check √(AVE)> factor loading, Bold=√(AVE)

Av R^2	*Av Com.*
0.47	*0.76*
Gof =	*0.60*

Goodness of fit Calculation: Gof = SQRT((Avg R^2)(Avg Com.))*

Gof > 0.31 recommended

Figure 167 SEM K.5 quality overview and Fornell - Larcker criterion.

SEM K.5 Resultant Model

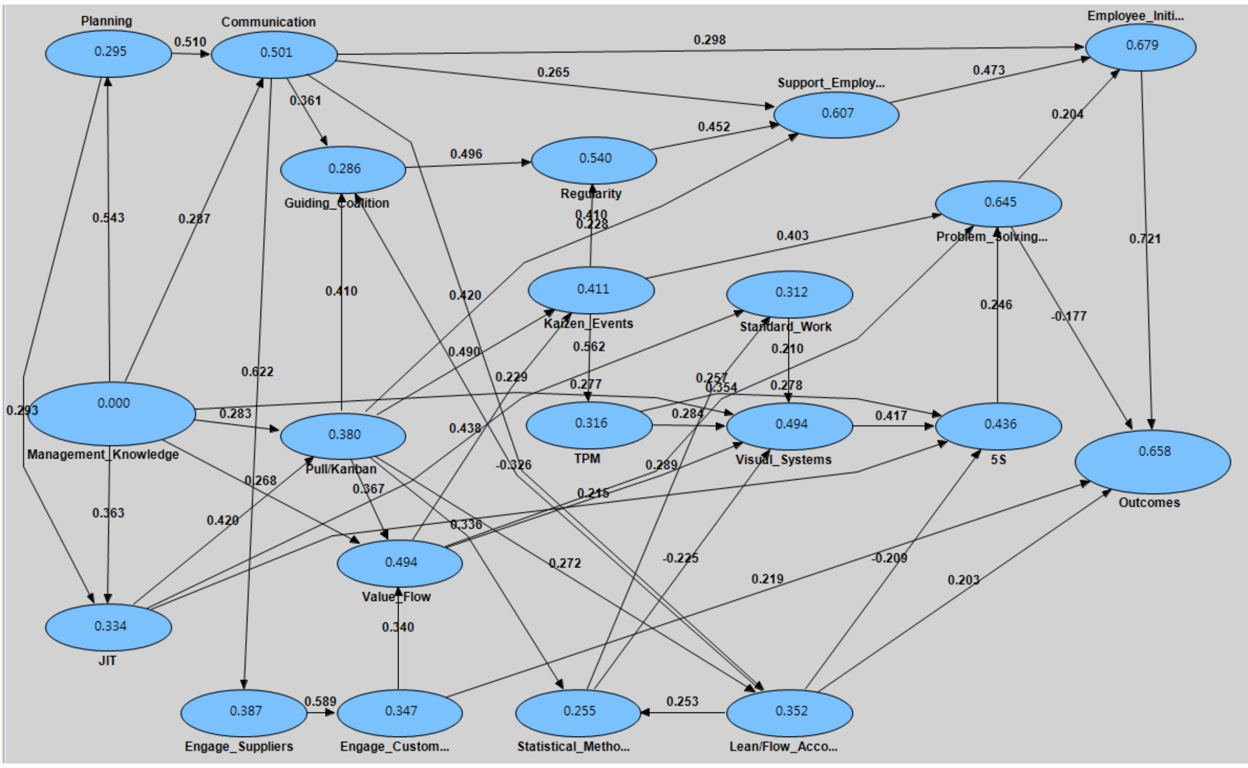


Figure 168 SEM K.5 resultant model of the Lean Knowledge-Based View for the high-variety low-volume scenario (96 lean and lean six sigma cases, 90%+ complete, all paths significant with p<0.025, bootstrapped 5000 times, individual sign changes allowed).

Negative relationships and p>0.01 highlighted	Original Sample (β)	Sample Mean	Standard Deviation	Standard Error	T Statistics	p -value (Significance)
Management Knowledge->Communication	0.29	0.29	0.10	0.10	2.78	0.00670
Management Knowledge->JIT	0.36	0.36	0.11	0.11	3.23	0.00175
Management Knowledge->Planning	0.54	0.54	0.09	0.09	6.14	0.00000
Management Knowledge->Pull/Kanban	0.28	0.29	0.11	0.11	2.51	0.01393
Management Knowledge->Value Flow	0.27	0.26	0.10	0.10	2.76	0.00717
Management Knowledge->Visual Systems	0.28	0.28	0.10	0.10	2.67	0.00910

Figure 169 SEM K.5 direct effects of Management Knowledge

Negative relationships and p>0.01 highlighted	Original Sample (β)	Sample Mean	Standard Deviation	Standard Error	T Statistics	p -value (Significance)
Engage Customers->Employee Initiatives (Enabled)	-0.17	-0.17	0.08	0.08	2.12	0.03667
Lean/Flow Accounting->TPM	0.22	0.22	0.10	0.10	2.22	0.02889
Pull/Kanban->Engage Suppliers	0.19	0.19	0.09	0.09	2.13	0.03622
Problem Solving (Simple)->Regularity	0.23	0.24	0.11	0.11	2.12	0.03653

Figure 170 SEM K.5 borderline paths (paths 0.025>p<0.05 removed for clarity)

Negative relationships and p>0.01 highlighted	Original Sample (β)	Sample Mean	Standard Deviation	Standard Error	T Statistics	p -value (Significance)
Problem Solving (Simple)->Outcomes	-0.18	-0.18	0.08	0.08	2.31	0.02316
Value Flow->Kaizen Events	0.23	0.24	0.10	0.10	2.34	0.02176
Lean/Flow Accounting->5S	-0.21	-0.21	0.09	0.09	2.35	0.02093
Lean/Flow Accounting->Statistical Methods	0.25	0.26	0.11	0.11	2.41	0.01815
Pull/Kanban->Support Employees	0.23	0.23	0.09	0.09	2.41	0.01808

Figure 171 SEM K.5 five least significant paths

Negative relationships and p>0.01 highlighted	Original Sample (β)	Sample Mean	Standard Deviation	Standard Error	T Statistics	p -value (Significance)
Employee Initiatives (Enabled)->Outcomes	0.72	0.73	0.08	0.08	9.53	0.00000
Communication->Engage Suppliers	0.62	0.62	0.07	0.07	9.02	0.00000
Engage Suppliers->Engage Customers	0.59	0.59	0.09	0.09	6.79	0.00000
Kaizen Events->TPM	0.56	0.56	0.07	0.07	7.75	0.00000
Management Knowledge->Planning	0.54	0.54	0.09	0.09	6.14	0.00000

Figure 172 SEM K.5 five largest path coefficients.

Negative relationships and p>0.01 highlighted	Original Sample (β)	Sample Mean	Standard Deviation	Standard Error	T Statistics	p -value (Significance)
Employee Initiatives (Enabled)->Outcomes	0.72	0.73	0.08	0.08	9.53	0.00000
Engage Customers->Outcomes	0.22	0.22	0.07	0.07	2.93	0.00441
Lean/Flow Accounting->Outcomes	0.20	0.20	0.07	0.07	2.77	0.00697
Problem Solving (Simple)->Outcomes	-0.18	-0.18	0.08	0.08	2.31	0.02316

Figure 173 SEM K.5 direct effects on Outcomes.

Negative relationships and p>0.01 highlighted	Original Sample (β)	Sample Mean	Standard Deviation	Standard Error	T Statistics	p -value (Significance)
Problem Solving (Simple)->Outcomes	-0.18	-0.18	0.08	0.08	2.31	0.02316
Lean/Flow Accounting->5S	-0.21	-0.21	0.09	0.09	2.35	0.02093
Statistical Methods->Visual Systems	-0.23	-0.23	0.07	0.07	3.03	0.00327
Lean/Flow Accounting->Guiding Coalition	-0.33	-0.33	0.10	0.10	3.39	0.00107

Figure 174 SEM K.5 negative relationships observed.

SEM K.5 Outcomes

Given the explorative nature, the high-variety low-volume model strongly explained variance in Outcomes with an R^2 of 0.66 (66%). The following results were significant to this work.

- This was the second strongest model in explaining Outcomes (Outcomes R^2 =0.66).

- **The strongest direct relationship with Outcomes is from Employee Initiatives (enabled) (β=0.72).**
- **Of all SEM K, this was the strongest relationship from any construct to Outcomes.**
- Of all SEM K the only path stronger was the relationship between JIT and Kanban[159] in large business (β=0.73) and high volume low variety manufacture (β=0.78).
- Employee initiatives are strongly influential in describing the success of implementation in high-variety low-volume manufacture.
- Engaging Customers to Outcomes was the second strongest direct relationship with Outcomes.
- Engaging Customers to Outcomes path coefficient (β=0.22) was only 30% of Employee Initiatives to Outcomes.
- Lean/Flow Accounting had a similarly weak direct relationship with Outcomes (β=0.20) Lean/Flow Accounting was one mediation path for the effects of Pull/Kanban on Outcomes.
- The strongest chain of causality was from Management Knowledge through Planning, Communication and Employee initiatives, as in the other models.
- Additional strong paths occurred to Outcomes through Guiding Coalition, Regularity, Support Employees and Employee Initiatives (enabled), as was common in the other SEM K models.
- Again, the key components of implementation were explained directly or indirectly by Management Knowledge.

A direct negative path was observed from Problem Solving (simple) to Outcomes.

- Problem Solving to Outcomes had a β=-0.18 path. Indicating overuse of problem solving with adequate involvement of employees.

Other negative paths were:

- Lean/Flow Accounting to 5S β=-0.21, Statistical Methods to Visual Systems β=-0.23, and the strongest Lean/Flow Accounting to Guiding Coalition β=-0.33
- The above negative paths showed an over emphasis on certain methods without considering other critical success factors i.e. customer engagement and staff enablement. The result was negative effects, compromising the implementations.

In general:

- The advanced processes, represented strongly by Pull/Kanban are mediated to Outcomes by the application of simple techniques (represented by TPM, 5S, Visual Systems and Standard Work). The main effects of all these methods are mediated to Outcomes through Regularity, Support for Employees, and Employee Initiatives.

[159] JIT and kanban are highly related as kanban is a component of a JIT pull system.

Again, the SEM showed that the effects of leadership and enabling employees on outcomes were significant by themselves, the strongest in each model. These were also mediators between the lean methods and success.

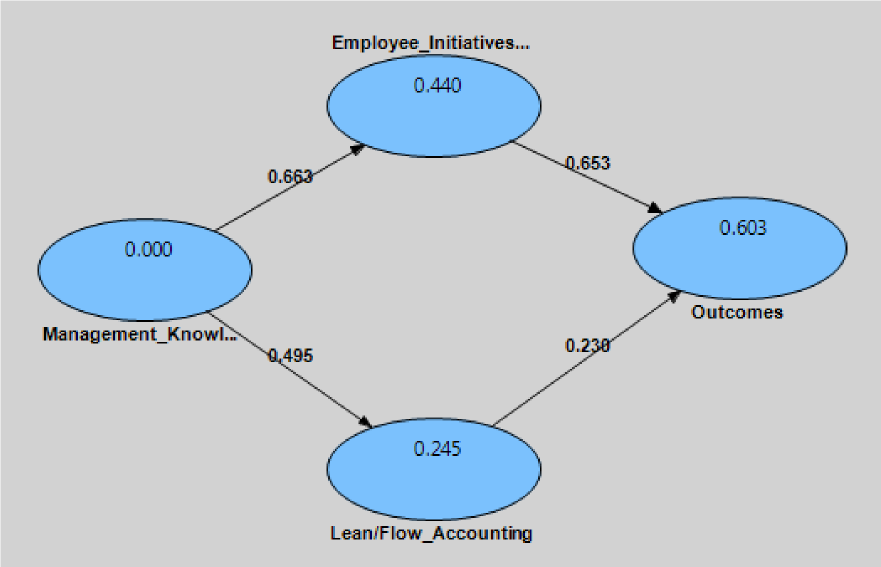


Figure 175 SEM K.5 simplified representation; Management Knowledge to Outcomes fully mediated by Employee Initiatives (enabled) and Lean Accounting. All paths significant with p<0.002 (model bootstrapped 5000 times with individual sign changes).

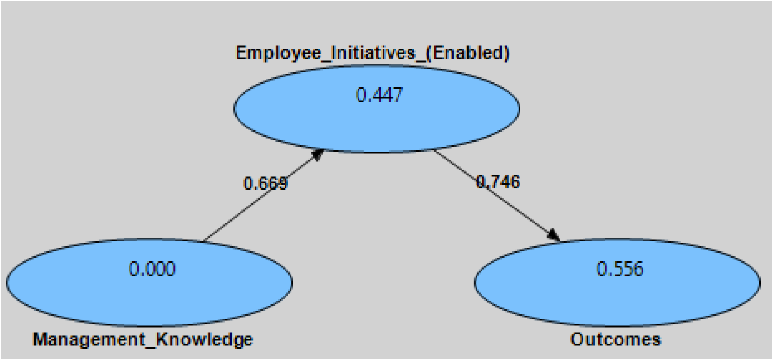


Figure 176 SEM K.5, simplified representation: the effects of Management Knowledge on Outcomes as fully mediated by Employee Initiatives (enabled). Management Knowledge to Outcomes was insignificant β=0.12, p=0.16 (model bootstrapped 5000 times with individual sign changes).

The significant effects of leadership enabling employee initiatives are represented in the SEMs in Figure 175 and Figure 176. These SEMs show:

- 60% of the variance of Outcomes was explained by Employee Initiatives and Lean/Flow Accounting acting on Outcomes (91% of the 66% variance explained in the full SEM K.5)
- 55% of the variance of Outcomes was explained by Employee Initiatives acting alone on Outcomes (83% of the 66% variance explained in full SEM K.5)
- Employee Initiatives were explained substantially (45%) by Management Knowledge (R^2=0.45, β=0.67).

Most of the variance in Outcomes (explained by SEM K.5) can be explained by management knowledge expressed in the enabling of employee initiatives.

8.3.6 Outcomes, SEM Analysis of the Lean Knowledge-Based View

The causality of Lean Implementation Success was represented in a strong exploration[160] of the Lean Knowledge-Based View. This exploration provided further insight to the ranking of factors by showing relationship between key factors. Specifically, the effects of leadership and enabling on Outcomes are significant in themselves, the strongest in each model, but are also the overriding mediators for advanced lean process and simple methods.

These are expressed in the acceptance of the sub hypotheses made with some specific clarifications noted below:

H B.1 Accepted	Outcomes of lean are substantially explained by communication (employee alignment); enabling employee initiatives; having momentum/regularity and building culture; supporting employees with change; management planning, the extended value stream (engaging customers and suppliers) and the methods of lean.
H B.2 Accepted	Strong relationships exist between management knowledge and the success factors: communication (employee alignment); enabling employee initiatives; having momentum/regularity and building culture; supporting employees with change; management planning, the extended value stream (engaging customers and suppliers), and the methods of lean.
H B.3 Accepted	As per Hypothesis 2*:* The tools or methods of lean are secondary. The primary aspects are leadership and enabling development
HB.3 Clarification:	This was true in the general case and the majority of situations tested. However, *in the low-variety high-volume case the methods were equally beneficial*.
HB.4 Accepted	The aspects of change leadership and employee enablement are the key success factors independent of business size and product mix, whereas key methods will be situationally specific to business size and product mix. Some methods (e.g. visual systems and simple problem solving) are supportive of employee enablement benefiting all scenarios.
HB.4 Clarification:	Accepted as illustrated by the clarification to HB.3
HB.5 Accepted	In high variation low volume manufacture the enabling aspects will be particularly important, describing the majority of the benefits from lean.

[160] Further exploration may unveil more or different lines of causality. For example causal direction between having a guiding coalition and planning unclear and may be mutually supportive.

HB.6 Accepted	In small business (10-100 employees) and in high-variety low-volume production the simple methods will correlate with successful outcomes and more advanced process improvement (e.g. JIT) will not.
HB.4 Clarification:	Kanban/Pull systems were important in these case but not the more advanced process methods (e.g. JIT).
HB.7 Accepted	In larger business (101-500 employees) the advanced process methods will correlate with outcomes more significantly.

Most of the variance in outcomes can be explained by management knowledge, expressed through employee support and the enabling of employee initiatives. This was the strongest line of causality in each case. This is particularly evident in small businesses (11-100 Employees) and especially in high-variation low-volume manufacture. In these cases, employee initiatives supported by leadership and simple lean techniques (e.g. visual systems and problem solving) explained the majority of outcomes. In low-variation high-volume manufacture the advanced lean processes increased in importance but strong mediation by employee support occurred. In the low-variation high-volume case, *supporting employees with the change* was the main mediator. Employee Initiatives was the main mediator for outcomes in all other cases.

- Significant negative correlations were observed with Outcomes and between other constructs. This was especially true in low-variation high-volume manufacture.
- Management knowledge (including the contextual knowledge, from learning and participating) was observed to describe the positive outcomes of lean implementation, describing the significant factors, especially leadership and enablement of employees.

This SEM analysis confirmed the significance of taking the knowledge-based view of lean. It shows the importance of management understanding lean and the risks (benefits and detriments) of implementation i.e. for the management of the risks through informed leadership participation.

8.3.7 Mediation of Lean Knowledge for Commitment

In order to claim the importance of lean knowledge a or the root cause success factor; a comparison of it with management commitment was necessary.

The importance of management commitment is expressed strongly in literature, as summarised by Worley & Doolen (2006) and emphasised in later works (Balle & Balle, 2009, p. vii; T. A. Boyle et al., 2011; Hines et al., 2008, 2011). Emphasis of commitment is equally referenced by practitioners; this was seen in questionnaire text responses. 333 comments were made of additional factors of lean that participants felt important. 95 of these comments (29% of the 333) expressed management commitment was very important. Only 10 of these comments (10% of the 95, 3% of the 333) mentioned management knowledge was important.

> The importance of management commitment is in literature and is reasonably tactile to practitioners. The importance of management knowledge is not emphasised by literature neither is it tactile to practitioners.

The relative importance of management commitment and knowledge was tested with PLS-SEM mediation. Mediated and unmediated path coefficients were reviewed. Basic mediation criteria were applied according to Baron and Kenny (Baron & Kenny, 1986) and the Sobel test was employed for additional evidence.

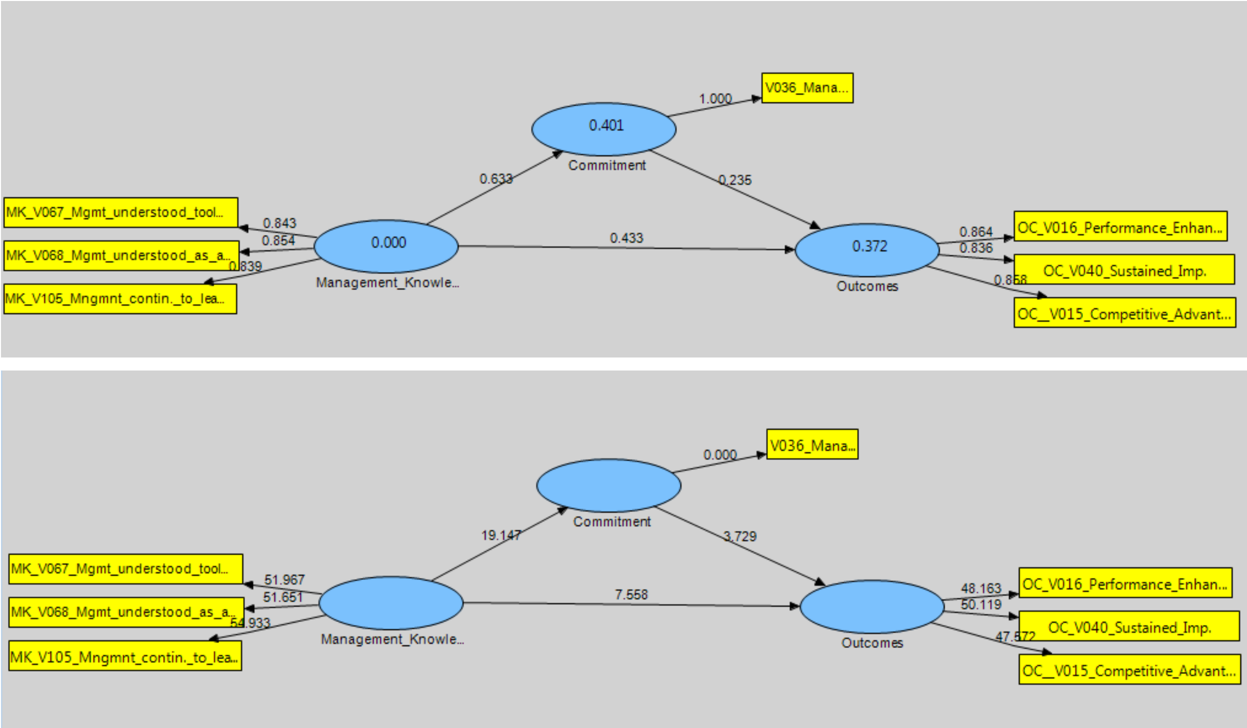
Sobel Test, Normality and Sample Size

For this specific case, the Sobel test (Sobel, 1982) was used to compare the significance of the mediations. The Sobel test is restricted by assumptions of normality and requires an adequate sample size. According to the study by MacKinnon et al. (MacKinnon, Lockwood, Hoffman, West, & Sheets, 2002) for the product of coefficients methods (of which the Sobel test is) sample sizes of 1,000, 100, and 50 are appropriate for detecting small, medium, and large effects respectively. Where for small effects 2% of the variance in the dependent variable is explained, for medium effects 13% of the variance in the dependent variable is explained and large effects 26% of the variance in the dependent variable is explained. Sample sizes were suitable for detecting the medium to large effects observed (see resulting SEMs).

In this analysis, the Sobel test calculator of Daniel Soper was used (Soper, 2013).

8.3.8 Effects of Management Knowledge Mediated by Commitments

The effect of Management Knowledge on Outcomes as mediated by Management Commitment was tested. With no mediator, the direct effect of Management Knowledge on Outcomes was $\beta=0.59$. The direct effect with the mediator reduced slightly to $\beta=0.44$ (Figure 177). The direct effect remained highly significant in the mediated model ($t=7.6$, i.e. $p=0.0000000000003$). The Sobel test (Figure 178) was significant at $p=0.00026$ (Soper, 2013). This analysis showed a weak partial mediation of Management Knowledge to Outcomes by Commitment.



Bootstrapped individual sign changes 5000 times L-LSS all 90%+data.
For t-values are 1.65 for 10% (α=0.1), 1.96 for 5% (α =0.05), 2.58 for 1% (α =0.01).

Figure 177 The effect of Management Knowledge on Outcomes as mediated by Management Commitment.

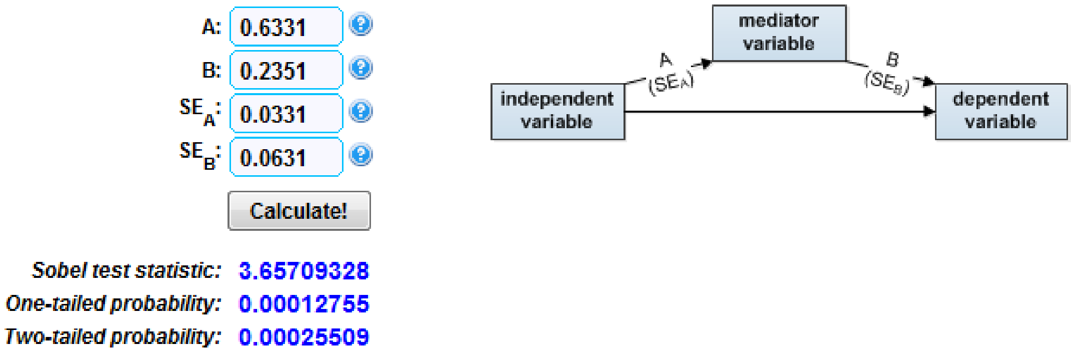
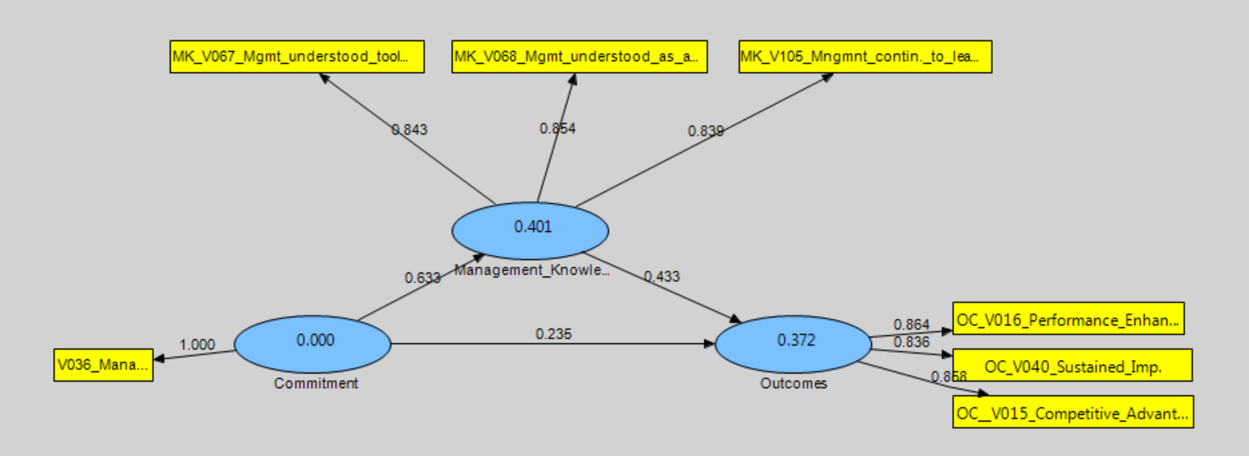
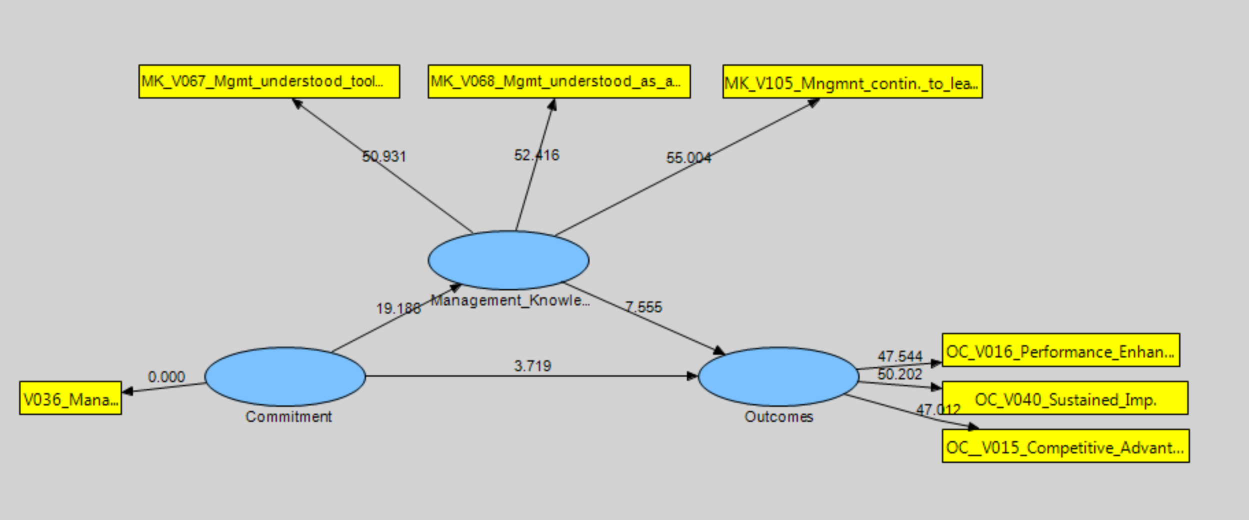


Figure 178 Sobel test for Management Knowledge effect on Outcomes mediated by Management Commitment, p=0.00026 (Soper, 2013).

8.3.9 Effects of Commitment Mediated by Managers Knowledge

The effect of Management Commitment on Outcomes as mediated by Management Knowledge was tested. With no mediator the direct effect of Commitment on Outcomes was 0.52. The direct effect with the mediator was reduced significantly to 0.24 (Figure 179). The direct effect was still significant in the mediated model (t=3.7, i.e. p=0.00022). The Sobel test (Figure 180) showed highly significant mediation with p=0.00000000, that is beyond the eight decimal places shown by the software (Soper, 2013). This analysis showed a very strong mediation of Commitment to Outcomes by Management Knowledge. But as the direct effect (Figure 179) was still significant (p<<0.01), it can only be called partial mediation.





Bootstrapped individual sign changes 5000 times L-LSS all 90%+data.
For t-values are 1.65 for 10% (α=0.1), 1.96 for 5% (α =0.05), 2.58 for 1% (α =0.01).

Figure 179 The effect of Management Commitment on Outcomes mediated by Management Knowledge.

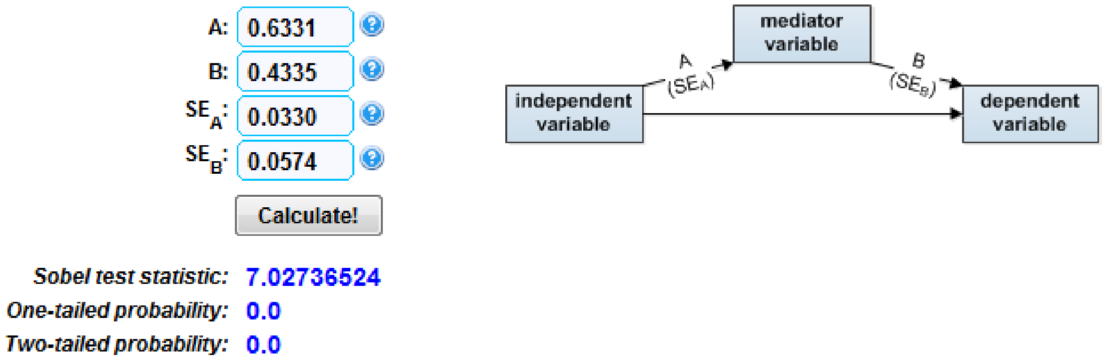


Figure 180 Sobel test for Management Commitment effect on Outcomes mediated by Management Knowledge, p=0.00000000 (Soper, 2013).

8.3.10 Mediation Test Summary

Effect on Outcomes		Path coefficient		Significance p	
Effect of:	Mediated by:	Not Mediated	Mediated	Direct Path in mediation	Mediation Test (Sobel)
Knowledge	Commitment	0.59	0.44	0.00000000	0.00025509
Commitment	Knowledge	0.52	0.24	0.00022926	0.00000000

Figure 181 Mediation summary: the effect of Management Commitment and Management Knowledge on Outcomes.

A mediation summary table is shown as Figure 181. The introduction of Commitment as a mediator between Management Knowledge and Outcomes showed:

- Only a small 0.15 drop in path coefficient (0.59 to 0.44).
- A direct effect that is still very highly significant.
- A Sobel test that is significant but not that high.

The introduction of Management Knowledge as a mediator between Commitment and Outcomes showed:

- A large 0.28 drop in path coefficient (β from 0.52 to 0.24), twice the drop observed by Commitment as a moderator.
- A direct effect was significant but not very high for data set size (393 cases, p=0.0002).
- A Sobel test that is highly significant, much higher than observed by Commitment as a moderator (p=0.00000000 cf. p=0.0002).

This analysis proves lean knowledge strongly mediates the effects of management commitment to outcomes. In other words:

- Management knowledge is stronger than management commitment in describing Outcomes.

Or that management knowledge, including learning and participation in implementation (see page 63), describes more of the causality for lean success than commitment alone.

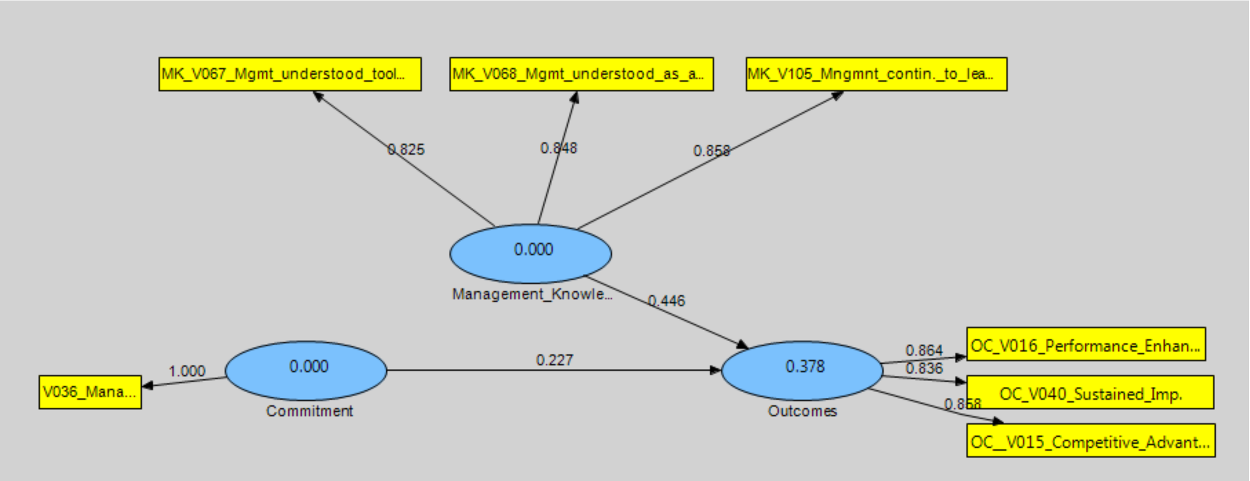


Figure 182 The effect of Management Commitment and Management Knowledge on Outcomes.

The simple SEM in Figure 182 expresses the findings, showing a weak 0.23 coefficient from Commitment to Outcomes but a much stronger 0.45 coefficient from Management Knowledge.

8.4 SEM C—The Consultant-Based View of Lean

Here we investigate the contemporary approach to lean, the consultant-based view. The Lean Knowledge-Based View is believed to be the best approach to lean, however the common approach to lean is hiring an expert consultants to assist and drive the implementation.

8.4.1 Testing Indicator Loadings for a Consultant Construct

Appropriate constructs were investigated. The three available variables; the extent consultants were used in implementation (V035), the extent they acted as coaches (V073), and their capability (V065), did not load well together. This is illustrated for V035 and V073 in Figure 183; this figure shows poor loadings when categorising by consultant capability. Better loading is observed where consultant capability was masterful but still were uneven, and favoured coaching 0.7 to 0.9.

- The differential loadings necessitated the use of single indicator constructs.

		Consultant Construct Indicator Loadings in Simple Model (shown below)	
Data Set (consultant capability)	Number of cases	V035 Extent consultant was involved in the implementation. .	V073 Extent consultant coached others.
Generic (all cases that used consultants)	312	-0.14	0.84
Capability Basic - No	54	0.94	0.55
Capable Consultants	118	0.63	0.95
Masterful Consultants	98	0.73	0.90

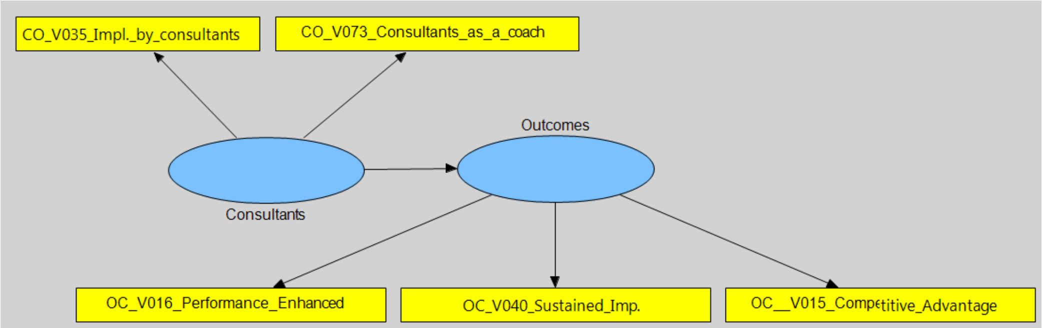


Figure 183 Consultant construct investigation. Poor indicator loadings were observed in this test SEM.

8.4.2 Effect of Consultant Capability on Outcomes

A simple SEM was developed to analyse the effects of consultant capability. The SEM tested the direct effects of capability on outcomes, and the effects with their implementing ad coaching. The hypothesis model was run for the generic case; Figure 184 shows the paths tested and Figure 185 shows the resultant model. The data set was built from the 312 cases where consultants were used.

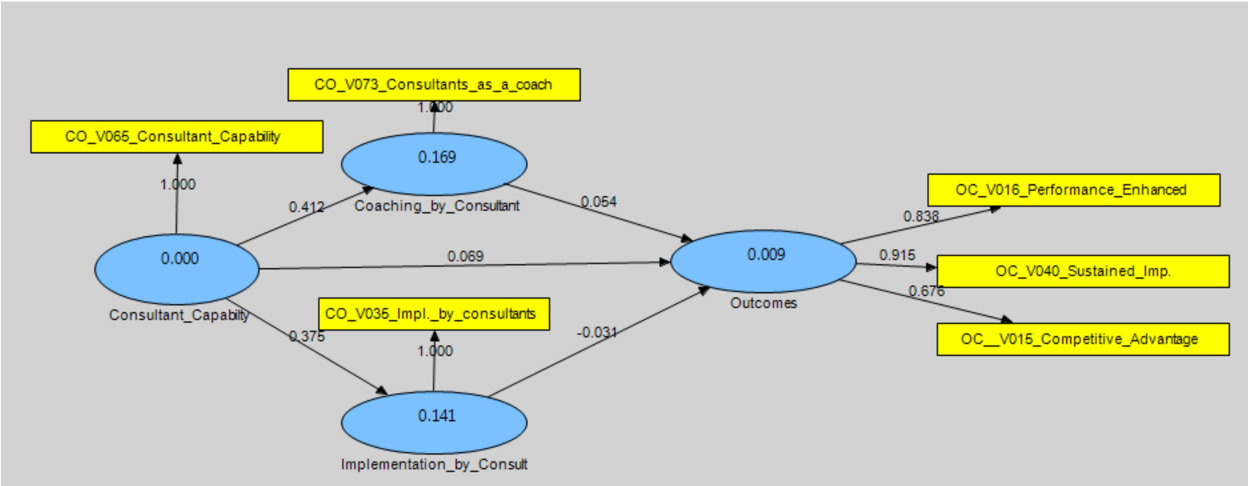
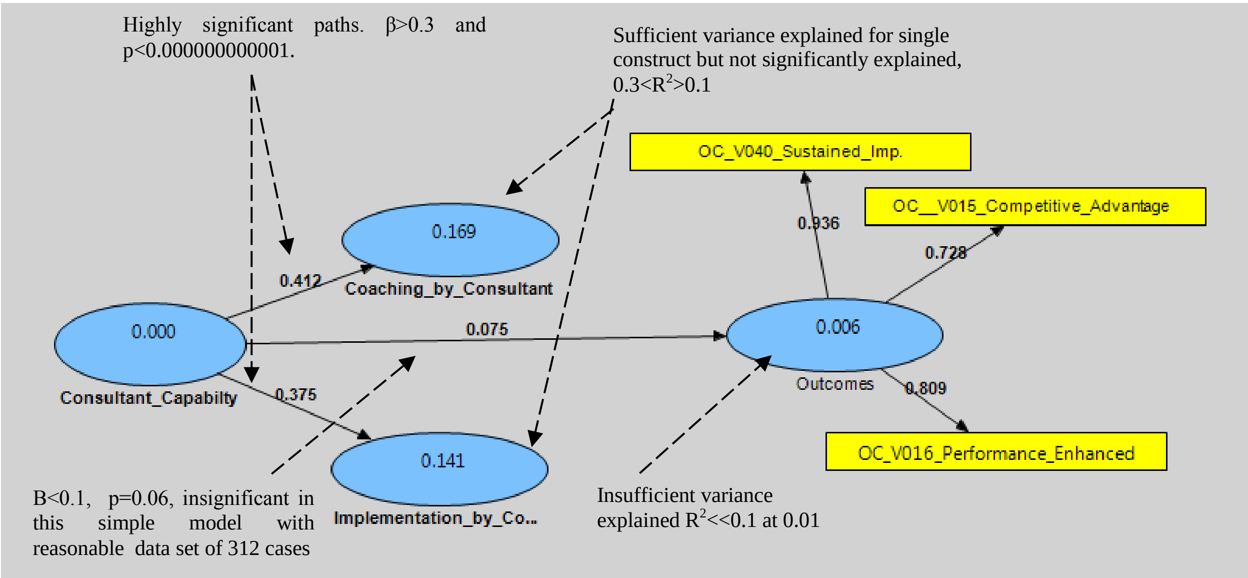


Figure 184 SEM –simple SEM of the Consultant-Based View: hypothesis model as run for the generic case (312 L-LSS cases where consultants were used). All paths are shown to outcomes as per hypotheses made.



	Original	Sample Mean	Standard	Standard	T Statistics	p-value	
Consultant_Capabilty->Coaching_by_Consult	0.41	0.41	0.05	0.05	8.29	0.0000000000000	
Consultant_Capabilty->Implementation_by_C	0.38	0.37	0.04	0.04	9.01	0.0000000000000	
Consultant_Capabilty->Outcomes	0.08	0.11	0.04	0.04	1.79	0.07408	Insignificant

Figure 185 SEM–simple SEM of the Consultant-Based View: hypothesis model as run for the generic case (312 L-LSS cases where consultants were used, Bootstrapped 5000 times, individual sign changes). Outcomes were not explained by consultant capability.

The extent that a consultant was involved in implementation or coaching was described weakly by their capability. Significant β values (~0.4) were observed for this but construct variance was only explained to

17% and 14%. No relationships were observed to Outcomes from consultants' coaching or implementation involvement. And, Outcomes was not explained by the consultants' capability; the path coefficient showed a low, β=0.08, and R^2<<0.1 at 0.01 i.e. only 1% of variance explained.

As an outcome:

- This simple model illustrates the weak, insignificant effects of consultants on outcomes (in the general case).

Further investigation of the Consultant-Based SEM was conducted categorising the data by consultant capability.

8.4.3 Moderating Effects of Consultant Capability

Consultant capability alone did not directly affect Outcomes but indications were it acted as a moderator. Moderation analysis made these effects apparent; a *multi-sampling* approach was used (Henseler & Fassott, 2010, Chapter 30; Rigdon, Schumacker, & Wothke, 1998). The *multi-sample* approach is recommended as being *"more suitable under the greatest variety of circumstances"* (Rigdon et al., 1998).

- The effects of consultant coaching and their implementation involvement, were analysed at different levels of consultant capability.

A simple hypothesis model for the direct effects of Coaching by Consultant and Implementation by Consultants is shown in Figure 186. The mediation relationship between Coaching by Consultant and Implementation by Consultant was kept in the models, showing the significant mediation. The model shows the path direction between Coaching by Consultant and Implementation by Consultant was to be adjusted according to the mediation that developed.

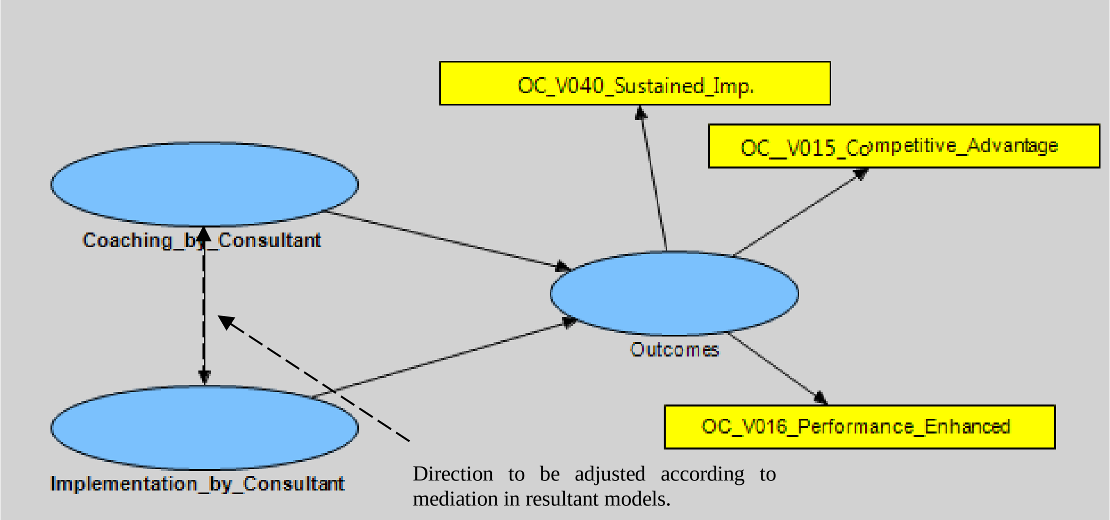


Figure 186 A simple SEM analysis model for the Consultant-Based View of lean Outcomes

The data was categorised into three sets for multi-sampling. The SEM for each is presented along with bootstrap data for all paths (based on hypothesis model). The data sets were:

- Consultants rated basic/no ability, Figure 187.
- Consultants rated capable, Figure 188.
- Consultants rated masterful, Figure 189.

It was hypothesised that:

HC.1 Masterful consultants have positive effects on implementation and their coaching provides the strongest causal path (being positive).

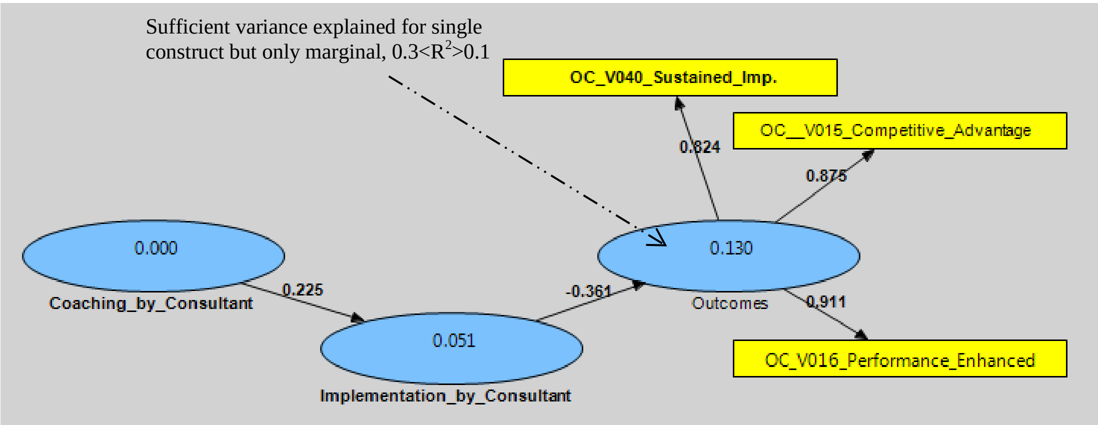
HC.2 Basic/no ability consultants have negative effects on implementation and their involvement in implementation provides the strongest causal path (being negative).

HC.3 Capable consultants have negative effects on implementation and their involvement in implementation provides the strongest causal path (being negative).

SEM C Models Quality

Indicators in the Outcomes construct loaded well (greater than 0.8) as expected. Consultant constructs only had one indicator and cross loadings were not a concern. Sufficient quality for exploratory analysis was observed from the simple path analyses with bootstrapping.

SEM C Results



	Original Sample	Sample Mean	Standard Deviation	Standard Error	T Statistics	p -value (Significance)	
Coaching_by_Consultant->Implementation_by	0.23	0.23	0.07	0.07	3.39	0.00136	
Coaching_by_Consultant->Outcomes	-0.07	-0.08	0.05	0.05	1.53	0.13332	Insignificant
Implementation_by_Consultant->Outcomes	-0.35	-0.35	0.06	0.06	5.72	0.00000	

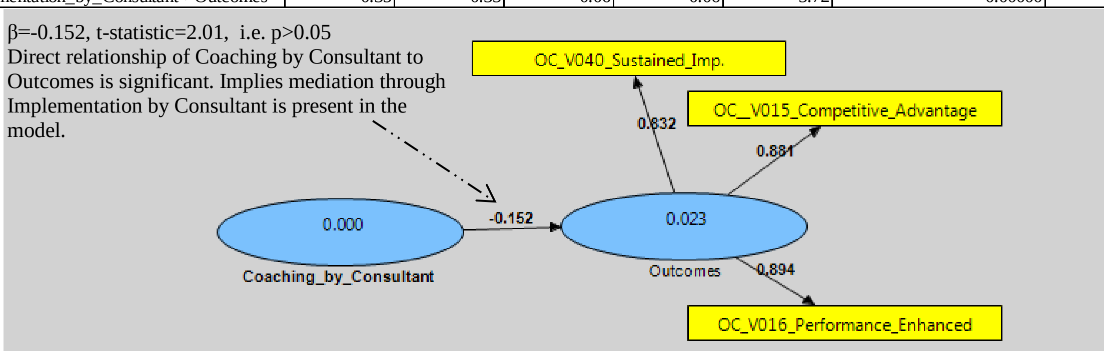
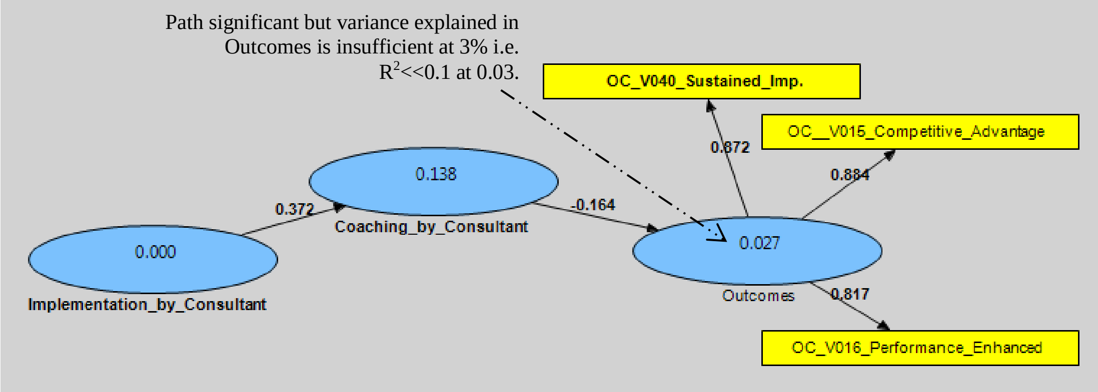
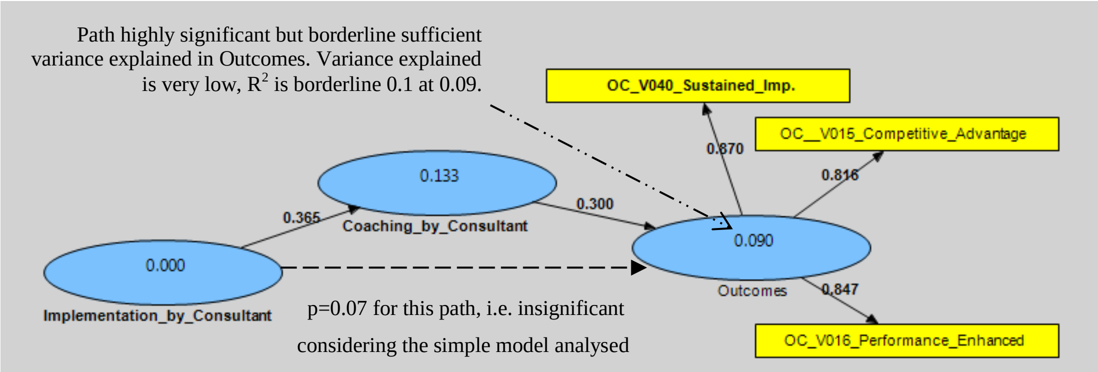


Figure 187 Simple SEM analysis model of the Consultant-Based View for lean (consultant capability=basic/no ability, 54 cases, bootstrapped 5000 times). Bootstrapping analysis for hypothesis model shown in the table.



	Original Sample	Sample Mean	Standard Deviation	Standard Error	T Statistics	p -value (Significance)	
Coaching_by_Consultant->Outcomes	-0.17	-0.17	0.06	0.06	2.66	0.00891	
Implementation_by_Consultant->Coaching_by	0.37	0.37	0.05	0.05	6.91	0.00000	
Implementation_by_Consultant->Outcomes	0.00	0.06	0.05	0.05	0.09	0.92995	Insignificant

Figure 188 A simple SEM analysis of the Consultant-Based View for lean (consultant capability=capable, 118 cases, bootstrapped 5000 times). Bootstrapping analysis for hypothesis model is shown in the table.



	Original Sample	Sample Mean	Standard Deviation	Standard Error	T Statistics	p -value (Significance)	
Coaching_by_Consultant->Outcomes	0.26	0.27	0.05	0.05	5.09	0.00000	
Implementation_by_Consultant->Coaching_by	0.37	0.36	0.05	0.05	6.80	0.00000	
Implementation_by_Consultant->Outcomes	0.09	0.09	0.05	0.05	1.85	0.06634	Insignificant

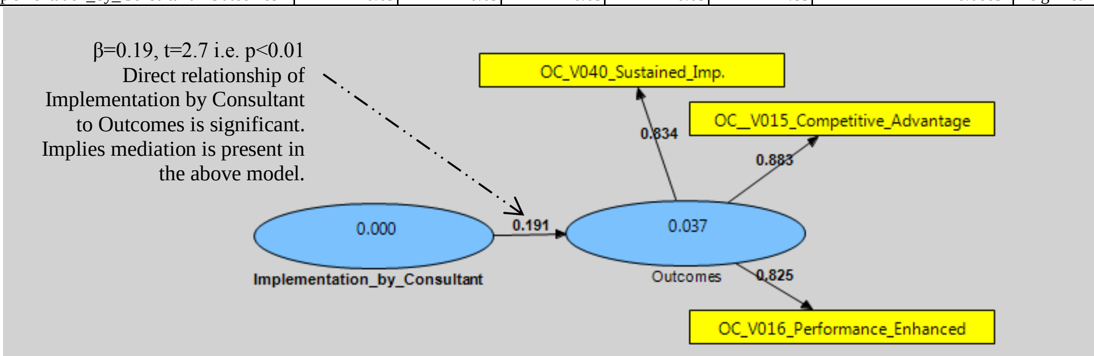


Figure 189 Simple SEM analysis model of the Consultant-Based View for lean (consultant capability=masterful, 98 cases, bootstrapped 5000 times). Bootstrapping analysis for hypothesis model shown in the table.

The only positive relationship to outcomes was observed for masterful capability consultant, see Figure 189. In that analysis, the Coaching by Consultant fully mediated between Implementation by Consultants and Outcomes. The path to Outcomes is acceptable (β=0.3) but less than 10% of variance in Outcomes is described i.e. R^2=0.09. Removing the indicator V040 Sustained Implementation from the Outcomes construct[161] decreased R^2 to 0.06. Removing performance indicators V015 and V016 and leaving just V040 Sustained Implementation in Outcomes, increased R^2 to 0.11.

There was evidence to accept HC.1 with clarification.

HC.1 Accepted — Masterful consultants have positive effects on implementation and their coaching provides the strongest causal path (being positive)..

Clarification: — The effects on Outcomes are very weak at R^2=0.09, the model as a whole could easily be rejected.

Negative relationship to Outcomes was observed for *capable* and *basic/no ability* consultants (Figure 187 and Figure 188).

In the *basic/no ability* category (Figure 187) Implementation by Consultants showed the strongest relationship to Outcomes and it was negative (-0.36). An adequate 13% of variance in Outcomes was described. In this data set a direct relationship was observed between Coaching by Consultants and Outcomes (-0.15, $p<0.05$). Implementation by Consultant fully mediated between Coaching by Consultants and Outcomes. There was evidence to accept HC.2.

HC.2 Accepted — Basic/no ability consultants have negative effects on implementation and their involvement in implementation provides the strongest causal path (being negative).

In the *capable* consultants category (Figure 188) Implementation by Consultants showed the strongest relationship to Outcomes and was negative, but weak, β=-0.16 ($\beta_{abs}<0.2$). An inadequate 3% of variance in Outcomes was described. There was no case to accept HC.2 and it was rejected with clarification.

HC.3 Rejected — ~~Capable consultants have negative effects on implementation and their involvement in implementation provides the strongest causal path (being negative).~~

Clarification: — Results show capable rated consultants had no significant negative effects on Outcomes; neither did they have any positive effects on Outcomes.

Figure 190 illustrates the effect of *V035 Extent implemented by a consultant* on Outcomes with the mediation of *V065 Consultant Capability*. This is a reasonable representative of the SEM analysis in graphical form due to the significant relationship between coaching and implementation by consultants for the masterful capability sample. The 3D plot illustrates the increased use of consultants is not at all beneficial. The exception is where the capability of the consultant is high. In that case, a very small benefit to outcomes (β=0.3, R^2=0.1 i.e. 10%) is observed through consultants coaching. Where capability is low the increased usage of consultants is negative (β=-0.36, R^2=0.13 i.e. 13%).

[161] These two experiments (removing indicators) included all paths and causal directions from the hypothesis model.

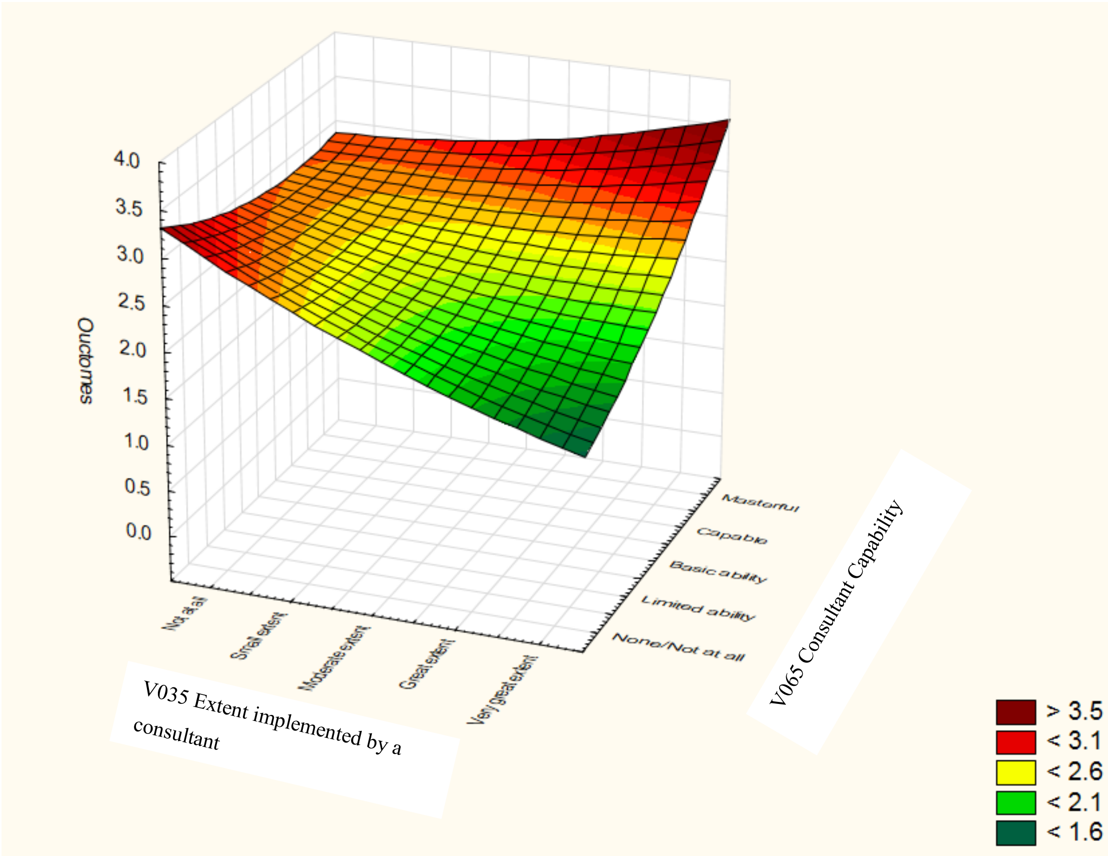


Figure 190 This 3D plot illustrates the combined effects of consultant capability and the extent lean was implemented by consultants on outcomes[162] (3D surface plot with quadratic fitting).

These results confirmed earlier findings from Pearson's r correlations analysis and discussion therein (Consultant Contribution, p. 229).

The strong indications are that:

- The consultant-based approach to lean (lean six sigma or otherwise) is the lean fad.
- It results in failure to deliver the desired outcomes and brings lean under criticism.

SEM C Implications for Further Work

Further development of the consultant-based view of lean and internal causality is beyond the scope of this work. Further SEM analysis would be beneficial to show what causes the positive and detrimental effects, that is what is overemphasised and underdeveloped. It is expected that the tools and processes are overemphasised whilst management knowledge, leadership, and employee enablement are underdeveloped. The exception may be when consultants are masterful and engage in much coaching.

[162] Outcomes equal the average of V015, V016 and V040 to equate to the Outcomes construct.

8.5 Outcomes

Partial least squares structural equation modelling (PLS-SEM) was used to test causal relationships that variable rankings could not address. Ultimately, because of complex interactions, many models were developed in order to understand the inner relationships. This work was exploratory and developed a sufficient understanding of the factors. Especially influential is the development of the Lean Knowledge-Based View.

These SEMs showed that the effects of leadership and enabling employees on outcomes were significant by themselves, the strongest in each model. These were also mediators between the lean methods and success.

Regarding management knowledge, the key factors for success (independent of implementation scenario) were described significantly by management knowledge. Managements' lean knowledge (including gaining experiential knowledge of lean in the context of their implementation) described the causality for success more than management commitment.

Additionally the common approach to lean, a consultant-based view was analysed. The increased use of consultants was not at all beneficial. The exception was where the capability of the consultant was high. In that case a very small benefit to outcomes (β=0.3, R2=0.1, i.e. 10%) was observed through the consultants' coaching. Where capability is low, the increased usage of consultants had a negative effect (β=-0.36, R2=0.13 i.e. 13%).

The consultant-based approach to lean (lean six sigma or otherwise) is the fad. It results in a failure to deliver the desired outcomes and brings lean under criticism. Practitioners should take a knowledge-based approach to lean implementation.

9. Discussion

Exploring many facets of lean implementation; the above statistical analysis has many implications. The hypotheses tested were formulated from *a priori* concepts of the contextualisation study and the literature review. *A posteriori* implications were also significant. Both of these are discussed in this chapter.

9.1 Addressing the Hypotheses

Sufficient evidence was gathered to address all hypotheses. Ultimately all hypotheses were accepted with some clarification:

> *Hypothesis 1: The major success and failure factor for lean is leadership knowledge.*
>
> ***Accepted***
>
> *Hypothesis 2: Consultants and the tools or methods of lean are secondary. The primary aspects are leadership and enabling development.*
>
> ***Accepted***[163]
>
> *Hypothesis 3: The key success factors for lean do not differ due to business size, and product mix.*
>
> ***Accepted***[164]
>
> ***Clarification: The importance of lean methods can be situationally specific; however the key success factors of leadership and enablement (including lean knowledge) are shown to be universal to lean implementation. These factors are even more critical in small businesses and high-variety low-volume industries.***

Hypothesis 2 and Hypothesis 3 were previously recast[165] in Statement 1.

> ***Statement 1 Leadership and enabling development are the primary factors for lean success. The key methods are visual systems, an effective communication process, and standard work. Particular techniques e.g. engaging customers, visual systems, and pull systems, are critical for specific situations. Consultants, unless masterful, do not help with long term performance and sustainability but could significantly hinder them. A masterful consultant can support positive outcomes through coaching.***

A synopsis of the supporting evidence is given below.

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[163] After applying variable ranking, Hypothesis 2 was accepted for lean generally but tentatively rejected for specific situations, i.e. for low–variation high-volume scenarios. Following SEM analysis this hypothesis is affirmed not only for the generic case but for all scenarios tested.

[164] See above note for Hypothesis 2.

[165] Recast after the hypotheses were tentatively rejected. See above notes.

9.1.1 Hypothesis 1—The Major Success and Failure Factor for Lean is Leadership Knowledge.

Developing a Knowledge-Based View of Lean.

The literature review concluded that lean has been proven to be beneficial and the critical success factors for lean have been substantially uncovered. However still the majority of implementations fail to sustain. Assuming the available knowledge is accurate, the many failed instances indicate that leaders do not utilise this knowledge. Thus their businesses generally fall into one of two categories: those who do not embark on lean or those who embark on unstained implementations of lean.

The concept of a knowledge-based view for lean was formed during the industry embedment. The industry case studies highlighted how important it was for management to develop lean knowledge. Many challenges were faced that needed particular skills for organisational leadership, the application of lean techniques, and the education of staff. Knowledge became the foundation needed to handle the many challenges of leading implementation. Conversely, a manager's lack of knowledge was highlighted as a key hindrance to success and factor of failure. A manager's knowledge is defined here as *the knowledge by which a manager makes decisions regarding the strategic direction and development of a business*. This knowledge is gained by personal pursuit, training, and experience.

In the first questionnaire lean knowledge was addressed in general and exploratory factor analysis (EFA) identified the holistic view of lean.[166] By SEM there was a strong relationship observed between lean knowledge and the holistic view of lean (β=0.49, $p<0.01$, R^2=0.24). There was also a significant relationship between the holistic view and perceived advantage (β=0.32, $p<0.01$) as well as a weaker direct relationship between lean knowledge and perceived advantage (β=0.23). This outcome confirmed H1 of chapter 6:

Ch. 6, **H1** The positive effect of *lean knowledge* on the *perceived advantage* of lean is mediated by the *holistic view* of lean.

The interpretation is that increasing lean knowledge develops a different understanding, the holistic view of lean. It is this understanding that mediates between lean knowledge and the perception of its benefits. The relationship between knowledge, understanding and perceived advantages were extrapolated to represent the outcomes of implementation (p. 189), but the actual relationship between a manager's knowledge and the outcomes were tested via the second questionnaire experiment.

In the second questionnaire experiment, the first analysis ranked variables by their importance to success. This method could not resolve (accept or reject) the hypothesised effect of management knowledge on success. However, the *extent management continued to learn and participate* in implementation (V105) was the top ranked variable, the single most important variable for predicting success. This variable related to

[166] The holistic view of lean is where lean is seen not only as tools and processes for eliminating waste, but as a business philosophy and strategy involving training and empowerment with respect for people

knowledge indirectly by representing an attitude of learning and willingness to participate.[167] It also relates directly by showing experiential knowledge, the knowledge of the developing implementation in the context of the business. In writing Hypothesis 1, a willingness to learn was presumed as a prerequisite. The high strength relationship between the attitude to seek knowledge and the success outcome was not so expected. In posterior analysis this is logical as it expresses the way a manager commits to gaining the knowledge. Other variables representing knowledge did rank in the in the top 25, however there was not enough evidence to accept Hypothesis 1. This is why structural equation modelling of the causal relationships between the factors and their combined effects on success was needed.

The structural equation modelling (PLS-SEM) showed that most of the variance in outcomes is explained by management knowledge expressed through change leadership with employee support and the enabling of their initiatives. This was the strongest line of causality in each model. Management knowledge[168] affected the positive outcomes by describing the significant factors, especially leadership and the enablement of employees. The key factors for success, independent of business size and product mix, were described substantially by management knowledge.

Management Commitment vs. Management Knowledge

Mediation relationships between outcomes, lean knowledge, and management commitment were investigated. This was necessary because the importance of management commitment is emphasised in literature and is reasonably tactile to practitioners. Conversely, the importance of management knowledge is only loosely mentioned by literature, and is not tactile to practitioners. This was confirmed through text responses in the questionnaire. 333 comments were made of additional factors of lean that were felt to be important. 95 of these comments (29%[169] of the 333) expressed that leadership commitment was very important. Only 10 of these comments (10% of the 95, 3% of the 333) mentioned leadership knowledge was important. Mediation tests were used to compare commitment and knowledge.

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[167] No doubt there are other implications to this variable. For example, this also implies a high level of commitment to *management by walking around* (MBWA).

[168] Management knowledge in experiment Two's SEMs was made up of three variables. It included knowledge of lean methods, knowledge of lean culture, and also contextual knowledge; that is management's learning and participating in the implementation.

[169] The question here asked what other factors the participant felt was important. Realise that the respondents had already been asked to what extent management had committed to the implementation and to what extent management had lean knowledge. The responses here are *emphasising for a second time* that commitment or knowledge was very important.

Management knowledge had a stronger relationship with the outcomes than commitment. Using commitment as a mediator between management knowledge and outcomes showed:

- Only a small 0.15 drop in path coefficient (0.59 to 0.44).
- A direct effect that was very highly significant (β=0.44).
- A Sobel test that was significant but not highly significant considering the number of samples (393 cases).

Placing management knowledge as the mediator between commitment and outcomes showed:

- A large 0.28 drop in path coefficient (β from 0.52 to 0.24) was observed, i.e. twice the drop by commitment as a moderator.
- A direct effect that was significant but not very high (β=0.24).
- A Sobel test that is highly significant, much higher than what was observed by commitment as a moderator (p=0.00000000 cf. p=0.0002).

The mediation tests confirmed that management's lean knowledge, including gaining the experiential knowledge of lean in the context of the implementation, describes more of the causality for success than mere commitment of management.

Accept Hypothesis 1

The research showed that increasing lean knowledge develops a holistic understanding of lean which promotes sound leadership decisions. These decisions lead to planning and communication for supporting employees with change and empowering their initiatives. This formed the strongest line of causality for success. Given the evidence above, Hypothesis 1 is well supported.

> ***Accept Hypothesis 1: The major success and failure factor for lean is leadership knowledge.***

9.1.2 Hypothesis 2—Consultants and The Tools or Methods Of Lean are Secondary. The Primary Aspects are Leadership and Enabling Development.

Hypothesis 2 expresses the importance of leadership and enabling development.[170] This hypothesis does not say that the tools and methods of lean are unimportant, but that they are secondary. During the industry case studies it was strongly evident that the developmental challenges faced necessitated particular skill in the application of organisational leadership. The testing of this hypothesis advances on the Lean Iceberg Model (Hines et al., 2008) by giving statistical evidence of the relative importance of the factors. More seminal was the inclusion of the impact of leadership knowledge and consultants.

[170] In this work, enabling development is related to employees and their being involved, aligned, and supported.

An initial variable ranking of the experiment Two data made steps to address this hypothesis. Variable rankings were filled with aspects of leadership and very few tools or methods. Consultant variables did not feature in the top variable rankings (p. 223). The SEM analysis completed the testing.

Leadership with a Lean Knowledge-Based View

The SEMs of different business sizes and product mixes were needed to address this hypothesis. As mentioned, the strongest line of causality in each SEM was from management knowledge through aspects of leadership, employee support and employee initiatives to outcomes. This line of causality was particularly strong in the small business analysis and even stronger in the high-variation low-volume manufacturing cases. In these cases, employee initiatives supported by leadership and simple lean techniques,[171] explained nearly all of the outcomes. In low-variation high-volume manufacture the advanced lean processes increased in importance. They explained much more of the outcomes than previous models but not directly. Strong mediation occurred through employee support.[172] This evidence addressed tools and methods relative to leadership and enabling development but did not address the contribution of consultants.

Consultant Contribution and the Consultant-Based View

Managers commonly approach lean by delegating their leadership responsibility to a consultant. This is diametrically opposed to their taking a knowledge-based view. SEMs showed that the use of consultants had no direct effect on outcomes, except when moderated by their capability. Multi-sampling by consultant capability showed three things. Firstly, *masterful* consultants had a positive effect on implementation outcomes through much coaching, but the effect was weak, explaining only 9% of the outcomes. Secondly, consultants of *basic/no ability* (Figure 187) had a stronger effect. A negative (-0.36) relationship was observed through their implementation activity. This explained 13% of the variance in outcomes. Finally, in the *capable* consultants category (Figure 188), a negligible effect was observed (β=-0.16, R^2=0.03).

Accept Hypothesis

The results of the knowledge-based view of lean with the consultant-based view of lean gave strong evidence to accept Hypothesis 2.

> ***Accept Hypothesis 2: Consultants and the tools or methods of lean are secondary. The primary aspects are leadership and enabling development.***

9.1.3 Hypothesis 3—The Key Success Factors For Lean Do Not Differ Due to Business Size, and Product Mix.

Hypothesis 3 addressed situation specificity and in this way builds on the previous hypotheses. The categorical SEMs of the lean knowledge-based view tested this hypothesis. As hypothesised and discussed,

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[171] The simple techniques most relevant were visual systems, 5S, and simple problem solving.

[172] In the low-variation high-volume case, supporting employees with the change was the main mediator, whereas the main mediator for outcomes was employee initiatives in all other cases.

the primary factors for success were observed to be of leadership, employee support and enabling employee initiatives. But in low-variation high-volume implementations, specific methods like JIT, TPM and kanban, were more important. However, the strongest effects were still observed through planning and support for employees. In this SEM the strongest chains of causality were (A) from management knowledge through planning to outcomes directly and (B) from planning to outcomes mediated through communication, employee initiatives and support for employees. This was sufficient evidence to accept the hypothesis.

Accept Hypothesis 3: The key success factors for lean do not differ due to business size, and product mix.

The importance of lean methods can be situationally specific, however the key success factors of leadership and enablement including lean knowledge are shown to be universal to lean implementation. These factors are even more critical in small business and high-variety low-volume industries. The key factors did not change with the different business sizes or extremes of the product mix modelled.

9.1.4 Hypothesis 4—New Zealand's Senior Managers (Represented Largely by Those In SMEs) Have Been Slow to Pick Up Lean Management.

Hypothesis 4 addressed the lean knowledge saturation in New Zealand. The background work identified lean as being worthwhile to pursue in New Zealand, and successful cases did exist in New Zealand from the early stages of lean thinking (late 1980's). Unfortunately, the industry review and embedment pointed to a lethargic attitude toward lean.

Lean knowledge saturation was investigated by country.[173] Differences between the United States and New Zealand were observed for the manufacturing sector (Figure 50, also p. 397). The mean familiarity for the United States scored 3.6 out of 4 whilst New Zealand scored only half that, 1.8. Further responses from the United States (ref. Figure 224) would be desirable. This would further increase confidence, and reduce bias but the statistical results were still strongly significant, $F(1,87)=9.2$, $p=0.00003$. Therefore Hypothesis 4 was accepted.

Accept Hypothesis 4: New Zealand's senior managers (represented largely by those in SMEs) have been slow to pick up lean management.

The evidence indicates that New Zealand managers have been lethargic towards obtaining lean knowledge. The implications of this are significant given the uncovered importance of lean knowledge as an overriding success factor. This is amplified with the prevalence of small business and high variety low volume operations, where leadership knowledge, being applied in enabling development and initiatives of employees, was shown to be even more critical. The lack of knowledge itself could be attributed to the prevalence of small business in New Zealand, with owners and managers time constrainted and focusing on the daily running of the business, more than the development of leadership and bringing in of new knowledge. This could be observed in the low lean familiarity found in owner operators.

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[173] The general population did not show any significant differences between countries.

9.2 Implications

To further assist the understanding of the detailed statistical analysis, a qualitative interpretation is given below. This also identifies the implications for practitioners considering implementing lean. Although the interpretation is subjective it represents the insights developed by the researcher.

Lean is Not a Fad

Experiment One showed that the perceptions of lean's advantages increased as knowledge and experience increased. This indicates that lean is not merely a fad. If shortcomings existed, experience would decrease the perceptions of lean's benefits, however the opposite occurred. This indicates that lean provides a true advantage over traditional ways. It also indicates these advantages can be secured by developing the proper understanding of lean through increased knowledge and experience. This further implied that; lean is failing to deliver not because lean itself is flawed but because of the way it is understood and applied.

Experiment One correlated lean knowledge with the holistic understanding of lean; in experiment Two the application of this understanding correlated with success. Experiment Two confirmed the inference that management's lean knowledge is a *root cause* success factor. This was seen by the direct and indirect effects of management knowledge on the critical success factors. A holistic approach through leadership knowledge, planning, communication, employee support, and employee initiatives, gave the strongest line of causality for success. With a base of lean knowledge, business managers achieved successful sustained implementation.

It was clear that there are significant benefits to lean that are not being realised because of the way it is understood. Because managers miss the holistic view of lean, they delegate leadership inappropriately, and expect lean leadership from lower levels without comprehension of what a successful lean implementation entails. Alternatively they quickly hire consultants to perform lean process improvement, neglecting the implementation risks. These actions result in many implementation failures. But the practitioners do not realise that their approach was the problem, not the methodology.

The problem with lean is not that it has a weak methodology or is just another fad; rather, the problem is that it is being misunderstood and misapplied. The real fad is for managers to embark on lean poorly, self-deceived (p. 168) that they know what true lean is.

Is Lean a Repackaging of Old Techniques?

The view of lean as a repackaging of old methods was also observed in experiment One. This view had weak negative correlations with lean knowledge. The weakness of the correlation indicates that it is not only practitioners with low levels of lean knowledge that have this understanding, but even some of those more familiar with lean also hold to this unhealthy view. This view brings with it a tools and processes approach, that is correlated with industrial engineering, and is associated with a top down management-centric implementation (Figure 57, p. 176). But it is healthier to have a holistic outlook, taking lean as philosophy and a strategy in itself. Although lean systems utilise many methods (Hines et al., 2004), their benefits are amplified by the way they are combined and integrated in a lean business system. In this way lean provides a significant competitive advantage beyond the popular methods and previous attempts at decoding the Toyota Production System. The view of lean as repackaging old methods is akin to viewing lean as a fad. For the advancement of lean success, these negative perception need to be addressed.

Tools Over Emphasised

In the series of SEMs compiled for the knowledge based view, negative correlations were observed between internal factors and implementation outcomes.[174] In multiple instances, the common methods (like 5S) were positively related to outcomes by employee support or employee initiatives, but their direct relationships showed significant negative correlations. This indicated a pitfall for managers was having an over emphasis of otherwise beneficial methods without proper leadership and employee engagement. It is implied that leadership was ignorant to these concerns and that they or the consultants became fixated on the process but neglected the people and a holistic view for lean success

Culture Worshiped

The importance of culture to success is emphasised in contemporary literature. Because of this, there was some expectation that seeing lean as tools and processes would have had a negative correlation with lean knowledge. Respondents to questionnaire One did not reflect this. Rather, lean as *tools and processes* was prominent in both low and high knowledge levels of lean. The extent that lean was considered as tools and processes actually increased with lean familiarity ($F[1,359]=8.7$, $p=.0033$) and competitive advantage ($F[1,327]=4.4$, $p=.036$). Similar increases were observed for lean as *new systems and ways*.

The importance of tools was also seen in the variable rankings and SEMs of questionnaire experiment Two. The effect of the various tools was situation specific and required wisdom[175] for their application but nonetheless they did affect success indirectly through having structure, regularity, and employee initiatives. In the case of high-volume low variation manufacture the JIT pull system showed very strong causality for success, although this was based on leadership knowledge and contingent on employee support. Various methods also support the development and maintaining of a lean culture. For example, an effective communication process builds up this culture by sharing the vision, supporting employees with change, and developing their improvement initiatives. Communication is supported by tools like A3 management in the nemawashi process. Another example is the PDCA process which supports the culture of continuous improvement with regularity and review. Additionally, standard work and visual systems support the employees, scripting the desired behaviours.

True lean has a focus on staff training and empowerment, which is important, but the process side should not be neglected. There are still significant advantages in using the tools and processes of lean. There is clearly a

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[174] This was especially true in low-variation high-volume manufacture.

[175] This refers to wisdom from knowledge and for decision making.

balance to be found between focusing on tools and methods versus developing the inherent human potential. The present danger is the developing of two camps of practitioners—the traditional camp seeing only tools and processes and the newer camp overly focused on culture. These two sides are both important and can work synergistically. The systems themselves should promote a culture of continuous improvement by supporting lean behaviours. Although the tools and processes may have been deemed insufficient, lean practitioners need to be careful in taking an entirely soft-skills view of lean.

Journey View vs. Planning

In the small business and low-variation high-volume SEMs, a particularly interesting relationship was observed, between planning and having a journey view. Although both variables played strong positive roles, they had a negative relationship, β=-0.43 between them (planning-> journey view).[176] This indicates, practitioners being overly relaxed in the approach to lean. This casual attitude to lean was also seen in the case studies. Recognising implementation takes time is appropriate, taking that as an excuse to avoid planning and building momentum is not. The implementation of lean, needs planning, regularity, and focus.

Low Saturation of Lean Knowledge

Lean knowledge saturation was shown to be very low. The survey indicates 88% of people were not at all familiar with lean. And of the remaining 12% with lean knowledge, only ¼ of them indicated a high familiarity with lean. In the manufacturing subset, knowledge of lean was low in 46% of participants[177] and considered high in 38%. Logically, the persons who don't know about lean and are not aware of its benefits would never apply lean. Of those familiar with lean, only a small number with high knowledge properly understand lean, the others are unlikely to succeed at gaining its benefits.

Managers and General Practitioners

Experiment One indicated that those who perceived the greatest advantage from lean held a higher understanding of lean. Experiment Two reinforced this higher and holistic view of lean; leadership and enablement of employees described the strongest paths of causality. Unfortunately the majority viewed lean as a set of tools and processes, a regurgitation of old methods forming a new fad. Practitioners need to see that taking lean as a business philosophy and strategy provides benefits that go beyond the common tools and processes approach. If they see these benefits, firstly, they will be more likely to implement lean, and secondly, they will implement lean in a proper way, rather than piecemeal.

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176 Near identical β values were observed (0.427 cf. 0.433) from otherwise different data sets. Also, the opposite direction, Journey View->Planning, was weaker for both models. The coefficients were β=-0.14 for low-variety high-volume and β =-0.21 for small business.

177 Percentages given here could have been moderated up and percentages for high knowledge level down to allow for known error in self-report (see Figure 208 on p. 13 and discussion on p. 38).

In-depth Knowledge for Risk Management

In-depth knowledge is needed for ongoing risk management. Although paralysis by over analysis should be avoided, the significant changes that occur in an implementation warrant careful risk management, because the effect of applying certain lean methods could result in negative outcomes.

The exploration by SEMs showed that certain factors had negative relationships with success. This indicated there was overuse or over emphasis of certain otherwise beneficial lean components. It is clear that lean is not only about maximising benefits by applying methods to improve processes, but it is also about mitigating the detriments of implementation. There are risks of setting back progress and ultimately failing through poor leadership decisions. To mitigate these detriments and maximise the benefits, an in-depth knowledge is required. Risk management results in a decision analysis based on an accurate understanding of the forces at play.

> An adequate knowledge of true, holistic lean and up-to-date knowledge of the context is essential to maximise the benefits and minimise the detriments with implementation.

Lean leadership becomes a decision making process. Whether a risk map is used (p. 117) or an alternative analysis process, decision making requires accurate information and the better the information, the better the decision. This demands continual gathering of knowledge within the context of the implementation, that is, continual learning and participation in the implementation. This was the single most important indicator of lean success in the data.

Management commitment to learn and participate in the implementation being the top predictor of success is a positive find for SMEs. The variable *management had excellent knowledge at the start of implementation* did not correlate as high. An immediate outlay of resources and time to become a full blown lean expert is not necessary. Managers should be happy to develop a good basic understanding of holistic lean and then progress further with their participation in the implementation.

Managers' Attitude

The managers' lethargic attitude towards learning needs to be broken down, along with the self-deception (p. 168) that "we know what lean is" and "lean is not relevant" (p. 192). To re-educate the first step may be to shout from the rooftops "You don't understand lean! You think you do, you may see 50% but that is not enough to have success, the other half is equally if not even more important". Managers need to recognise that there is a need for education or re-education of lean. There may be benefits to lean that they do not see, despite of what they think, lean may actually be relevant to their field. Results from experiment One (Figure 74, p. 192) indicated it is highly likely they do not really understand lean or how it is implemented.

Consultant Use

Finding an appropriate sensei to '*get the knowledge'*, has long since been recommended (J. P. Womack & Jones, 1996). The problem with this is a detachment of management from the implementation through inappropriate delegation.[178] A consultant-based lean approach was shown to have no benefit in the general case (analysis across all data). This is better than having a negative effect but barely. If no gains are made, continuous improvement methodologies will be discarded, and the business will be left behind by the competition.

Linear correlation gave insights into the contribution of consultants (p. 229). Results for low ability consultants showed poor performance in an unstained implementation, no new culture developed, and no development of a self-improving organisation. Both the consultant's involvement in implementation and their coaching correlated with the need for management to continually pressure the staff to maintain initiatives. There were indications of greater resistance among employees. Ideally an implementation should engage the employees so that the initiatives become their own, and therefore are sustained without management force. Management should walk the floor, spend more time observing the work, and listen to the employees; managers should spend less time relying solely on their consultants.

Only a minority (36%) of consultants were considered to be masterful, and even then they were only weakly associated with obtaining the benefits of lean. This indicates that most consultants practicing lean would not have a positive impact on success, but will likely have a significant negative impact.

This is a surprising result that contradicts the generally accepted practice of hiring consultants for lean implementation. It is highly probable that consultants in general over emphasise popular tools. Methods like 5S, TPM, and VSM can be taken to an extreme without developing crucial contingency factors. Communication for employee alignment, supporting employees with the change, and empowering them to make their own improvements are critical factors that are easily neglected in the tools approach. TPM is an example of a popular but overemphasised method. This was seen in the low-variety high-volume SEM (p. 273). TPM had a -0.24 correlation to lean outcomes. Undoubtedly the use of preventative maintenance is something positive, but if overemphasised, and not applied through employee initiatives it is detrimental.[179] However, consultants may become fixated on applying certain tools that they feel are appropriate, without acknowledging or engaging the employees.

Although the specific areas of coaching were not identified, weak positive effects (R^2=0.09)[180] were observed through masterful consultants' coaching. A masterful consultant may help with lean tools but it is

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[178] In principle whether the responsibility is delegated to a consultant or a more junior member of staff the result is similar. Leadership is not engaged in the process appropriately and does not develop the knowledge and wisdom to implement lean holistically.

[179] TPM was also associated with statistical processes in the SEM, and implies a discussion that was not taken up in this work.

[180] In SEMs an R^2 of 0.1 is considered the minimum acceptable, even by exploratory standards.

assumed that developing leadership's knowledge and ability in handling change is the most effectual use of their coaching. There is room for consultants in the form of coaching with change and expert support with specialist activities but not for inappropriate delegation of leadership. Lean is not just getting in a smart person, e.g. a graduate or statistician to make the process more efficient. The management needs to own lean through understanding it, driving it, and participating in implementation. In so doing they are developing the self-improving capability of the organisation from within, as opposed to the externally driven process improvements. If a consultant contributes to this kind of change they can have a positive and lasting effect on implementation.

What is evident is that much care needs to be exercised in choosing consultants. Wisdom is needed for ensuring they fill the right function without conflicting with the critical development of the organisation. It is crucial that management develop adequate knowledge for effective decision making regarding any supporting services. This is especially true when only 36% of the consultants are observed to have positive effects.

Education and Re-education for Lean Success

It is acknowledged that experiential learning is most effective but *general education* can still provide *lean learning. The goal is to develop lean knowledge and advance lean success.* If a company wants to be successful in lean, adequate knowledge must be developed. If the government wants to advance the success of lean it needs to provide or promote the adequate education.

Key to these improvement methodologies is systems thinking (e.g. TOC and lean flow). It is undoubtedly difficult for new practitioners to see and apply this kind of thinking, but it is a grave concern that so many apparently capable, educated, and experienced persons (as surveyed) would not understand real productivity in the sense of a system. However, instead of focusing on this core competency in being productive, cost accounting and its traditional methods, that lead in the opposite direction, are being drummed into the majority of professionals (Figure 209). The truth is that most educators are likely to have no knowledge of lean and default teach old management methods.

Education should develop a high and balanced view of lean. Unfortunately much of the tacit knowledge in industry exists at a low knowledge level, exhibiting a tools and processes view. This low view is supported by the promotion of lean six sigma certification, which in the majority of cases promotes a tool based project. It is believed that a higher view of lean can be developed quickly if the correct education is provided. Re-education of industry would increase appreciation of holistic lean. However, a critical mass is needed to overcome the perpetuating of the tools and processes view. This raises issues with how lean learning takes place. For example "lean learning networks" and other discussion forums for likeminded lean professionals, promote the current tacit industry knowledge and progress is slow. But if someone within a group can take a real leap in their thinking, developing knowledge of holistic lean, the whole forum would benefit.

Lean re-education needs to target the organisational development aspects that are usually neglected in the tools and processes view. In questionnaire One, training and empowerment of staff showed the greatest differences observed and saw the most significant effects. The next largest and highly related effect was with *respect for people*. Following this was lean in its holistic approach as a business philosophy and strategy. The aspects of implementation identified by exploratory factor analysis (EFA) should not be neglected: sound communication, staff participation and regular focus with small but continuous improvements (Figure 57, p. 176). The principle for teaching should be this: start by explaining leadership for organisational development supported by lean techniques, especially visual systems and simple problem solving accompanied by basic pull systems. Avoid giving the impression of lean as a multiplicity of methods with an implementation driven by consultants.

Development of the holistic view was associated with high familiarity and extensive experience. This needs to change. The holistic view is not especially complicated as a concept and need not take a long time to develop. The critical mass in industry is moving the wrong way and what is needed is some to turn them through a proper and well-rounded education. Government support through education would be more advantageous than funding consultant. The empirical proof in this work, highlighting the factors and benefits of holistic lean, can help shift the mindset and updated frameworks for understanding holistic lean would also be beneficial. The author is concerned that the New Zealand government's lean initiative, Better by Lean, will lose focus, be neglected and eventually be disestablished as the TWI programme was in the 1980's (see pp. 88, 94). In a sense this would not be surprising, because the politicians themselves will be in the category of managers who don't understand lean or its benefits, resulting in the danger of lean ultimately failing in New Zealand.

Governing Bodies and Education

Governing bodies should take the initiative to build lean into the education of professionals, by including lean and related *systems thinking* in the standard curriculum. Although lean thinking has proven beneficial it is not built into general education. Only 12% of participants are familiar with it (Figure 74, p. 192),[181] of that 12% the majority have a tools and processes view. The study showed that personal drive or business needs motivated ~60% of participants to pursue lean, whilst 29% were introduced through employment, and less than 7% indicated exposure through general education.[182] Although specialised lean training needs to be developed, there also needs to be general inclusion in other courses of study, especially where long term careers have a leadership function e.g. engineering, business, and medical degrees. Students should be taught how to think critically about the way they work and how their role affects the whole organisation. Professionals should not only offer their field's skill but also the continued improvement and productive application of those skills with lean systems thinking.

[181] And similarly for TPS and TOC.

[182] Survey population was relatively well-educated with 70% holding graduate or postgraduate degrees.

New Zealand Governing Bodies

As discussed in Chapter 6, New Zealand could use a wake-up call in the development of new lean programmes—to propagate holistic lean knowledge. This was indicated by how far New Zealand manufacturing participants were behind the USA, which identified the lethargy in New Zealand to seeking out new knowledge of lean. To develop true lean in New Zealand businesses, the lethargy and self-deception needs to be overcome. It was postulated that the indifference towards developed lean thinking is due to prior experience and erroneous knowledge. Such knowledge leads to inadequate or no implementations of lean. The contextualisation study discussions pointed to the role of management as the entrance gate for knowledge and the development of advanced lean capability. The concern is passivity among senior managers towards acquiring new knowledge. As an example; it is unclear how many of the managers that have taken the government's Better By Lean course really connected with or committed to true lean.

Promoting leadership's *commitment to understand lean* is especially crucial. The government's current Better by Lean programme provides a two day course and funding for consultant services. Rather than handing out government funding for consultants, managers should be tied into a programme of learning, personal development, and accountability with coaching from a sensei. The current way of support, by funding for consultants leads towards a tools approach and ultimately failure, missing the development of managements' capability. A knowledge-based approach to government led lean programmes will go further than the current consultant-based support.

9.3 Small Business Implementation Model

For a basic synthesis of the work and to provide benefit to practitioners, the causal models were simplified and developed into a practitioner stage model. The model was developed for small businesses. However, as critical factors were common across the situations analysed, this model could easily be applied to alternative scenarios.

Time Constraints

In regards to small manufacturing enterprises, how to educate them is a key issue. Lethargy or not, their issue is resource constraint, especially time. The second most frequent excuse for not pursuing lean was time[183] (20%, Figure 74, p. 192). To counter this, lean's key aspects need communicating in a succinct structured manner. Simple and succinct implementation models can go a long way to support this, breaking through the tools and process view, and giving enough insight to motivate further learning.

[183] Seeing lean as not relevant was the most common reason for not pursuing lean knowledge (i.e. 38%).

9.3.1 Engineering a Stage Model for Lean Implementation

In creating a stage process model for lean, two criticisms arose: change is not a discrete process and lean is best learnt by doing. Despite these viewpoints, a stage model is beneficial for a practitioner's guidance and can be engineered to script the critical steps of change.

Firstly, although the continuous and dynamic nature of change must be kept in mind, critical points of the journey can be identified. The initiation of an implementation is a planned-change; the initial steps from management, at least in broad terms, can be identified. It is in later stages that emergent change develops.

Secondly, the benefits of prior learning, as opposed to *learning by doing*, are debatable. Dr. Jeffery Liker's comment in *The Lean Manager* gives this perspective (Balle & Balle, 2009, p. vii):

> *"It [implementing lean] is enormously complex, yet unbelievably simple. The most complex part is that you can only learn this system by doing the work. Yet people want to be convinced intellectually before they are willing to make a commitment to doing it"*

Dr. Liker suggests lean is best learnt in practice (Liker, 2004, p. 260). Experience in practice is invaluable, however (and it is assumed Dr. Liker would agree), the better the training and guidance is, the better the first *experience* can be. There cannot be a practice round in implementations; in organisational change it is all real games (Liker, 2004, p. 187). Sustaining the implementation can be difficult if basics are not right the first time. This is particularly true for small businesses. In larger businesses it is possible to run a pilot with a subset of employees, but in an SME of 50 employees in one factory, it will be difficult to isolate some for a pilot. Besides the effects on company culture there may be additional cost for plant and equipment, among other organisational factors. A larger business may have the resources to absorb these but not the typical SME. It is extremely helpful, or crucial, to get the basics right the first time; some cultural setbacks or negative experiences can be long lasting and should be avoided. Even in larger businesses it may feel like there is only one shot at getting implementation right (Liker, 2004, p. 187).[184] Learning by doing is ultimately the best, but first time success in SMEs can be supported by guidelines. For illustration's sake, even though an experienced baker can improvise and bake an amazing cake, a recipe is invaluable in the first experience.

The formation of the model requires a degree of subjective interpretation or engineering. The problem with utilising only science is described by Shigley & Mischke (2003, p. 369):

> *"Often science fails to provide the answers which are needed…Engineers use science to solve their problems if available. But available or not, the problems must be solved, and whatever form the solution takes is called engineering."*

Along with what science was learned throughout this work, a solution for lean implementation was engineered to describe the process as much as possible.

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[184] This reference is to Ken Elliot's comment as the manager setting up a new Toyota service parts facility.

A change leader need not understand all the micro level science or psychology of change, for example all the factors and cycles of resistance. However, highlighting key treatments for typical issues and barriers of change are beneficial even if the full continuum of change is not mapped in entirety. The following framework was developed to script the critical moves for first-time lean change leaders.

9.3.2 Lean Transformation in a Small Business

The stage model for lean implementation in a small business is shown in Figure 191. The model includes two major sections, *Preparation and Deployment and one minor stream Consultant Alignment*. The emphasis within each of the major aspects changes as time progresses. The changing emphasis is implied by the changing width of the shaded bands. The model starts from a desire to learn and then progresses to build a learning organisation for operational excellence.

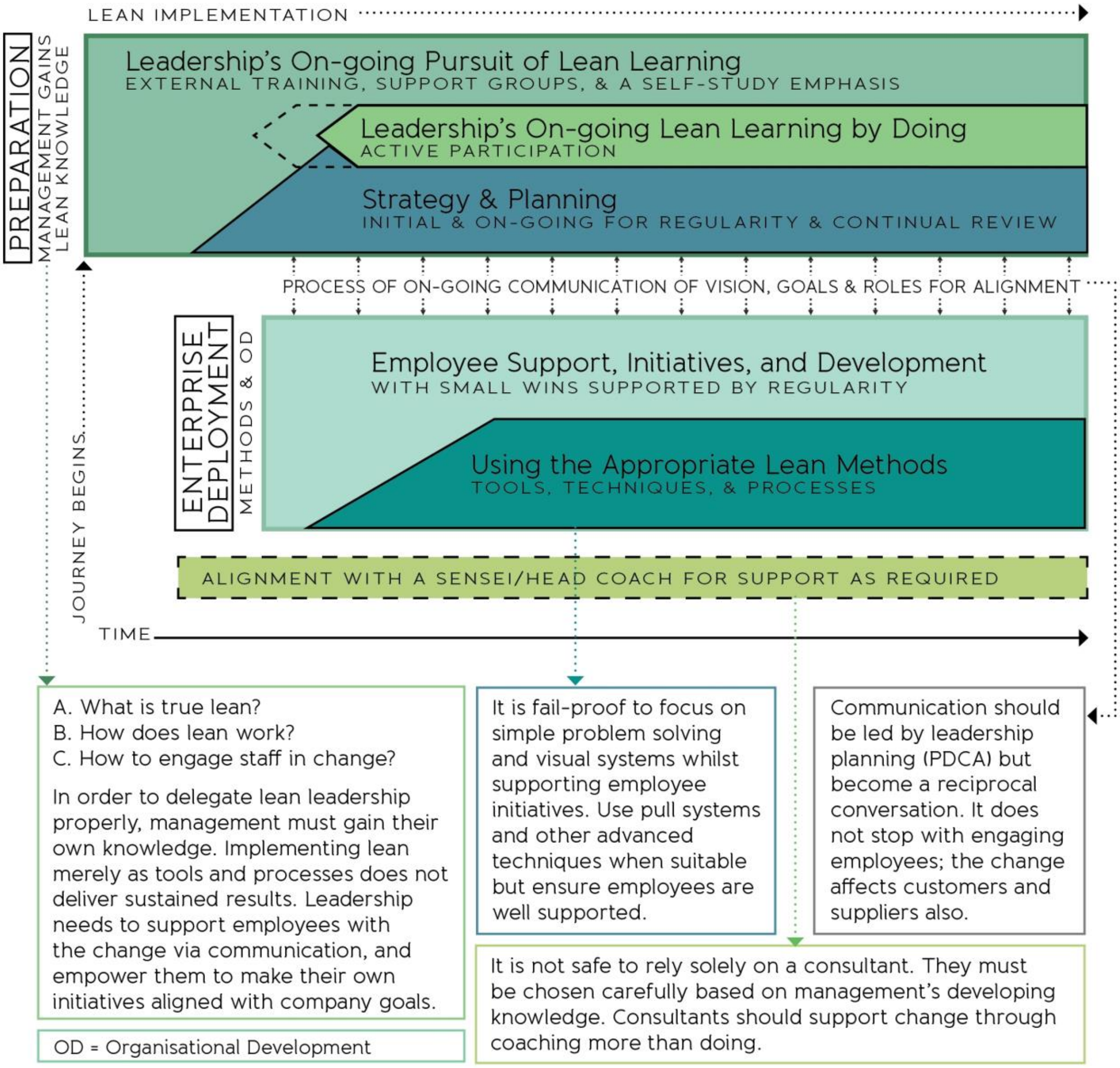

Figure 191 A lean implementation framework to support first time implementation by SME managers. This model gives an overview of the initial change process.

The resultant model is a simplistic representation of the critical success factors for initiating a lean journey. As well as organised entities for the spreading of knowledge, there has been a call for *"an easy to understand description of the approach, along with a typical sequence of activities"* (Sashkin, Burke, Lawrence, & Passmore, 1985). The intention in this model is not to represent all the causality of lean change, for that would cloud the key issues. For more complex models of causality, the reader can view the structural equation models (p. 239).

Preparation of Managers with Knowledge

The preparation aspect in Figure 191 includes on-going learning and on-going strategy and planning. On-going learning is further divided into two sections, learning by (1) studying and training, and (2) experiential learning. The sole emphasis in the beginning stage of an implementation is on-going learning by study and training. Once the implementation has begun, learning by studying and training will reduce, and the experiential learning will be very significant.

Management knowledge was shown to be a root cause factor for lean implementation success. By lean learning managers will be equipped in order to identify and treat the critical factors to maximise benefits and minimise detriments.

For the SMEs, it is especially pertinent for senior management to be equipped in this way. If the lean capability is only developed at lower levels, there is a higher risk of losing the investment through staff attrition. Thus when senior management obtains the proper understanding knowledge retention is secured.

If learning is the initiation of a lean implementation, then many failed lean implementations did not truly fail except that they failed to start. In this sense and according to this model they were not lean implementations at all but merely implementations of process improvement.

> Many lean implementations did not truly fail except that they failed to start. They were merely implementations of process improvement not true lean thinking.

After the initial period of learning, the strategy and planning for change will begin. This is likely to be a period of internal and external market analysis, simple SWOT and PESTEL, and an initial review of the businesses core processes, focusing on what the company is good at and where the company is headed with lean. There is a need to set the vision for the future and some identify some critical steps. This may include mapping the big picture in a form of VSM.

There will be significant situational challenges according to different business structures, existing cultures, product mixes, geographic locations and other custom factors. The decision making regarding these is supported by the developed lean knowledge.

On the surface the model may seem quite simple, not scripting all the moves. But the goal of this level of model is not to script all the moves but to script the critical moves for successful implementation.

The message delivered is this, lean is not mere process improvement and managers shouldn't rely on a consultant but must pick up adequate lean knowledge themselves.

Deployment

The deployment stage is where the "rubber hits the road". The manager's initial learning has been done, the draft strategy has been formed, and it is time to deploy lean. There should not be the thought of "doing lean" as a time-bound project. Becoming lean is a transformational change that is a journey towards perfection, not something that is done for a limited period of time only. However, there is a time when the change will transition from affecting a small team, e.g. a group of managers or key staff, to affect the whole organisation, the real beginning of organisational transformation. This is what is meant by deployment.

In the deployment stage the initial treatments for successful organisational change are believed to be the most important. The presenting of the vision, motivating for change, making first steps clear, developing a new identity for staff, and producing small wins is all part of this section. On the stage model this is labelled as "Employee support and development with small wins supported by regularity". This involves on-going communication of vision, strategy, and role alignment with staff. As was seen in SEMs, communication should not stop with staff but engage the extended value stream of customers and suppliers. All parties will be significantly affected by the change and need to see the benefits, being engaged in the process. This is especially true during any teething periods but should be maintained with PDCA cycles.

As the change progresses, the tools and methods of lean will become more and more an emphasis for process improvement by the engaged staff. The initial tools used will be targeted at getting the change going, gaining momentum, and making the change stick.

Alignment with Consultants

The way SMEs engage consultants needs serious review. If a consultant is employed, they should be engaged in a learning relationship as an expert coach, a sensei. The selection of a consultant must be carried out carefully and have a good understanding of lean sustainability and not just be an applicator of tools. A manager needs to be able to determine whether a particular consultant will help them produce the cultural change needed and not merely implement tools. This insight will come from the initial learning stage; the initial learning must not be passed over, it lays the foundation for the decision making in the rest of the implementation. Without it, managers can easily be led into a trap of the consultant-based view of lean.

As discussed previously, that the positive effects of consultants come through their coaching. The consultant's responsibility will be to ensure that a high level of training resource is readily available especially to the manager. The manager needs to show his strong commitment, to gain staff trust, and be able to make the right decisions in the context of their organisation. Providing a supporting presence, a consultant should help to maintain and establish regularity for a sustained implementation, but the implementation should not be driven by them. The relationship should be that of a coach or a sensei rather than a programme manager or an external industrial engineer. The latter is typical of a consultant-based view and results in implementations that fail to sustain. The implementation should not only sustain but even continue to gain momentum after a change agent or consultant has left.

9.3.3 Presentation at a Holistic Level

For initiating practitioner learning, the stage model of implementation (Figure 191) should be presented at a holistic level, outlining key aspects of lean and organisational development, including imperative methods. For example, the stage model could be combined with the illustration of top-down versus emergent change (Figure 29, p. 136) along with a discussion of flow and systems thinking, and introduction to leans key principles (Figure 6, p. 10). Practitioners should then be provided with a recommended reading list (p. 326) to initiate their personal lean learning journey.

It is debatable how much the initial presentation should include tools. On one hand, managers need an introduction to basic lean methods. On the other hand they can be side-tracked very easily when tools are highlighted too early; the holistic aspects could get overlooked. Regardless, guidance is eventually needed to introduce the kinds of tools that are most beneficial in their situation. The SEMs showed it is fail proof to focus on visual systems and simple problem solving with employee initiatives. It is also very important to establish a communication process using tools like A3 management in a catchball process. However, standard work was especially important for SMEs, having a direct effect on outcomes (β=0.35). Excluding employee initiatives, this was the strongest relationship with outcomes out of all the models. Among the more advanced processes, pull systems such as kanban were seen to be the most impactful technique. The advanced techniques can be employed once practitioners have ensured that the employees are well supported. It is important that the excitement of quick performance gains do not override the leadership and engagement of employees with regularity for establishing the lean culture and ongoing successes. This discussion of method selection shows that lean implementation is a decision making process.

9.4 Risk Management in Decision Making

For managers considering where to start with lean, the primary implication of the lean-risk work is to take a staged approach, not merely focusing on the high impact methods. Before progressing to the advanced lean methods, it is recommend that they deliberately select components that will build lean culture through small wins and staff engagement. The research questionnaires did not ask about established risk management processes specifically. However, risk management is implied in the decisions made by leadership to leverage the critical success factors.

It is suggested that managers apply the risk matrix logic (p. 119) if not the exact method. By evaluating the impact of each of the lean principles and tools, and the difficulty of implementing them, *they can make decisions which are based on their specific organisational context.* The organisational context is very important, and the analysis is best done by someone who has a deep understanding of how the organisation operates. At the same time it is also important that the analyst understands the capabilities of the various lean principles and tools. Again, it is recommended managers do not solely rely on experts but should also gain the necessary lean knowledge through the excellent texts, e.g. Hines et al. (2011). The knowledge is needed even for consultant selection. This decision making, risk management process may be second nature to an experienced practitioner, but for the inexperienced the analysis tool could be invaluable, providing necessary perspective.

10. Conclusion

10.1 Thesis

The purpose of this work was to identify and explore lean success factors. This included the extent a business manager's own knowledge impacts success or failure of an implementation. This was a worthwhile exercise due to its potential to enhance productivity and the commercial success of New Zealand industries through successful lean implementations.

10.2 Contextual Body of Knowledge

The literature on lean implementation and causality for success has been predominantly contextual. Since the seminal MIT work (Holweg, 2007; Krafcik, 1988; J. P. Womack et al., 1990), the body of knowledge has typically been case study based. Though the general understanding of lean success factors was developed, it needed further delineation. There was a noticeable lack of empirical works beyond case study contextualisation. Thus in this work a method was developed to go deeper conceptually and empirically.

10.3 Approach

This work resulted in a systematic investigation of the factors and underlying causality for lean implementation success. An extensive exploration was accomplished through a multifaceted work producing contextual and conceptual findings based on industry contextualisation study (p. 86), as well as empirical findings through one survey of lean knowledge and one case-study questionnaire.

The *lenses* approach[185] to the literature review (p. 9) allowed for the division of the research problem and parallel thought development. By coupling the literature outcomes with contextualisation study interviews and cases studies, many factors for lean success were identified and tentative conceptual frameworks were built (pp. 125). The contextualisation study involved a study of lean practices in New Zealand and practical involvement in lean implementation; this industry embedment grounded the research in reality. Following this, the first questionnaire experiment explored how lean is understood (pp. 156, 189). Distribution returned 758 responses, a significant data set. The second questionnaire experiment gathered case data for exploring implementation actions and outcomes (pp. 197, 239).[186] Distribution gathered 1253 responses from over 44 countries, specifically 393 usable cases[187] of lean and lean six sigma.

[185] The lenses represented three bodies of knowledge; they were lean management, organisational development, and risk management.

[186] The specific outcomes of each facet are discussed in detail in their respective sections. Hence, this final discussion section is geared towards synopsis and concluding implications rather than repetition of discussion.

[187] Cases of 90% complete out of 87 questions.

10.4 Contribution

This multifaceted work produced contextual and conceptual findings based on the industry contextualisation study (p. 124) and significant data analyses. Statistical exploration included basic linear methods and more advanced algorithms, e.g. exploratory factor analysis and structural equation modelling (SEM). Multiple models of causality were produced as a result. The data from the first questionnaire enabled an analysis of both the public and practitioners' understanding of lean. The relationship between the participant's understanding of what lean is, the extent of their lean knowledge, and their perception of its advantages were modelled empirically (p. 188). Via the second questionnaire (implementation data), an exploration of the proposed factors and underlying causality for lean success was conducted. Models ranked lean success factors according to their importance (p. 223) and SEM exploration built causal models for implementation success. Both kinds of models were developed using multiple samples to show a generic implementation and its difference according to business size and product mix. Based on the results of the contextualisation study and questionnaire experiments, nine definite contributions advanced the body of knowledge. These contributions were methodological, conceptual, and empirical.

First, the exploration of lean success provided a methodological contribution, pioneering the questionnaire based approach with explorative structural modelling of a full scope lean implementation. This method allowed for seminal empirical outcomes, contributing statistical evidence to a body of knowledge based predominantly on case study contextualisation.

Secondly, structural equation models of the *lean knowledge-based view* (p. 240) provided a conceptual and empirical contribution showing the profound positive effects of management knowledge. Management lean knowledge resulted in sound leadership decisions that supported the employees with change and enabled employee initiatives. These were the primary factors for lean success. This outcome of the second experiment showed an implementation according to a holistic view of lean as opposed to a tools and methods approach. During the first questionnaire experiment, this view of lean was associated with a high level of lean knowledge. For lean success, managers need to commit to lean knowledge, developing their understanding of lean overall as well as in the context of their implementation by learning and participating.

Third, although leadership was most important, the benefits of specific lean methods were also highlighted by these models. Using visual systems, having an effective communication process, and implementing standard work were all shown to support lean success. Also, particular components of lean proved critical for specific situations, e.g. engaging customers and standard work for small businesses (11-100 employees), and pull systems (kanban) for high-variety low-volume manufacture.

Fourth, interestingly enough, structural models showed negligible and even negative effects for the contemporary consultant-based approach to lean (p. 291). Consultants did not benefit the long-term performance and sustainability of lean but could significantly hinder it, that is unless they were categorised as *masterful*, and only a meagre 36% of consultants came under that category. Linear correlation gave insights into the specific contribution of consultants (p. 229). Results for low ability consultants showed poor performance in an unstained implementation without a new culture being developed, and no development of a self-improving organisation. Both the consultant's involvement in implementation and their coaching correlated with the need for management to continually pressure the staff to maintain initiatives. There were indications of greater resistance among employees. Ideally an implementation should engage the employees so that the initiatives become their own, and therefore are sustained without management force. Masterful consultants supported positive outcomes through coaching; although their impact was still weak (R^2=0.1, p.294). The implication regarding consultants was that managers need a basic education of holistic lean before selecting a consultant and should carefully choose one who is focused on coaching more than doing. Wisdom is needed to ensure they fill the right function without conflicting with the critical development of the organisation. It is crucial that management develop the adequate knowledge for effective decision making regarding any supporting services, especially true when only 36% of the consultants are observed to have positive effects.

Fifth, regarding lean knowledge in New Zealand, a shortage was observed. The survey results indicate that New Zealand manufacturing is well behind the United States in lean knowledge. Familiarity with lean in NZ participants averaged only half what the USA participants had in survey One. The results were highly significant, $F(1,87)=19.2$, $p=0.00003$. New Zealand industry would benefit greatly from its government addressing lean education properly.

Based on the above contributions the following hypotheses were accepted.

> ***Hypothesis 1: The major success and failure factor for lean is leadership knowledge.***
>
> ***Hypothesis 2: Consultants and the tools or methods of lean are secondary. The primary aspects are leadership and enabling development.***
>
> ***Hypothesis 3: The key success factors for lean do not differ due to business size, and product mix.***
>
> ***Hypothesis 4: New Zealand's senior managers (represented largely by those in SMEs) have been slow to pick up lean management.***

Sixth, although culture has been emphasised in the current literature, the extent that lean was considered as tools and processes actually increased with lean familiarity ($F[1, 359]=8.7$, $p=0.0033$) and competitive advantage ($F[1,327]=4.4$, $p=0.036$). Similar increases were observed for lean as *new systems and ways*. And as discussed, the importance of specific tools was also seen in the variable rankings and SEMs of questionnaire experiment Two. Specific methods, like A3 Management and visual systems even support the culture and behaviours of employees. True lean has a focus on staff training and empowerment, which is important, but the process side should not be neglected. It was proposed that the present danger is the developing of two camps of practitioners, the traditional camp seeing only tools and processes and the newer camp overly focused on culture. Both sides are important and work synergistically.

Seventh, another significant contribution was the integration of lean and risk management (p. 111). In the related literature there was a weak inference but no significant application of this. This work developed a simple risk analysis matrix, a qualitative risk map, for the selection and prioritisation of lean implementation components. The risk map could be used for assessing the methods, and visualising and communicating the challenges. It was applied in a case study and the logic was used throughout the work.

Eighth, some adjustments to government lean strategies were proposed, specifically education. The development of the holistic view of lean was associated with high familiarity and extensive experience but this association needs to change. True lean is not especially complicated as a concept, and it should not take a long time to learn the basic principles. However, the critical mass of the tactile knowledge in industry needs to turn. Ultimately, government support through true lean education far preferred over a consultant funding approach, which is used in New Zealand and abroad, and can do more damage than good.

The research showed that personal drive and business needs had motivated ~60% of participants to pursue lean, whilst 29% were introduced through employment, and less than 7% indicated exposure through general education. Current business education focuses on cost accounting, and its traditional methods instead of lean systems thinking as a core competency for being productive (Figure 209). It is hoped, that the empirical proof in this work along with simple training materials can promote holistic lean thinking. However, the government must drive this for the education of industry and the development of professionals. Although some progress has been made by the Better by Lean programme, the concern is that the New Zealand government will lose focus, the programme will lack development, lean education will ultimately be neglected, and the programme eventually disestablished, just like the TWI programme was in the 1980's. In a sense this should not be surprising, because the politicians themselves are in the category of managers who want to boost productivity but haven't taken the time to understand what can really benefit it.

Finally, besides contributing to the academic body of knowledge, the work directly supports industry practice, integrating the findings in a tangible stage process model (p. 314). A model for lean implementation in SMEs was developed along with the method selection matrix (p. 118). It is important that the knowledge experts have is presented to SME leaders in a palatable form. The problem with lean is not that it is a weak methodology and just another fad but rather it is being misunderstood and misapplied. The real fad is for business leaders to embark on lean poorly, under improper guidance, self-deceived that they know what true lean is. The main message of the model was to direct leaders to start their journey by gaining adequate knowledge of holistic lean.

This work contributed an advancement of the body of knowledge for lean organisational change. The dissemination of this knowledge has the potential to enhance productivity and the commercial success of industries within and beyond New Zealand through successful lean implementations.

10.5 Limitations

The main testing of the hypotheses was accomplished using exploratory models based on questionnaire data. This method had significant advantages but was not without limitations.

When building the questionnaires, relevant factors were contextualised from literature and contextualisation study, but it is possible that some aspects could have been missed. A small amount (1%) of responses to questionnaire One felt restricted by the ordinal scales, but no significant or new insights were identified by the free text responses. In the implementation questionnaire, of those who commented, less than 1% was negative about the general survey design.

When using web based questionnaires there is room for human error e.g. simply missing a question or answering wrong. This is not dissimilar to the possibility of a researcher's own data entry error. This risk to accuracy, along with the problem of subjectivity, is mitigated by the large data set.

Although unlikely, two people involved in the same implementation could have both filled out the survey. Even if this had occurred it would not influence the results significantly due to the large data set. Additionally, someone entering random data or filling out the survey twice is extremely unlikely due to the length of the survey.

Another limitation is the representation of a complicated scenario that changes with time by a selected number of questions. The time dimension was not easily captured i.e. how the implementation changed with time. A lean method may have been beneficial early on but may have become particularly detrimental over time.

An undeniable disadvantage of using a survey approach is the reliance on self-report. Questionnaires capture a person's opinion. In experiment One this is exactly what was desired e.g. "What do you think lean is?" Experiment Two however was more prone to errors of subjectivity. Although the survey did not ask opinion on what was best, it did ask for subjective ratings of the aspects and outcomes. These subjective self-assessments provide one opinion of the implementation and its outcomes in qualitative scales. However, in defence of the work, this is an acceptable approach for research in this field and it guards against the researcher's biasing the qualitative data had he gathered it himself.

Although the structural models themselves were large, their scales were not fully developed; the number of indicators for constructs was typically small (in some cases one). Additionally, more objective measures could be incorporated into the scales. Finally, the larger SEM models were discussed in broad terms. For example, variables were included for kaizen events and statistical methods but were not addressed conceptually much further than representation.

10.6 Implications for Future Work

The exploratory nature of this work provides many implications for further research. A number of these implications are discussed below.

Given that the broad exploration has been accomplished, the finer empirical work can be conducted. Further development of structural equation models for lean would be insightful. There were a limited number of subjective and objective measures used in this work and more could be developed. This could pull from existing works in other fields, such as general operations research, but new work on lean scales is also desired. More advanced scales could be developed for internal capabilities, communication, planning, employee support and especially knowledge and implementation outcome. Doing this will help to define the specific actions that leaders should make. Additionally, further investigation of internal causal effects and alternate operating modes (e.g. high-variation high-volume manufacturing) would advance the body of knowledge.

Implications of common methods such as kaizen events and statistical processes were lightly touched on and included in models but warrant further testing. These aspects are thought to be distracting and not that beneficial, possibly detrimental. Although scope did not warrant further investigation, this would be worthwhile in future work. Further investigation in smaller models could test mediation effects. The effects of kaizen events on outcomes, simple problem solving, employee initiatives and momentum of change could be investigated. The effect of statistical methods could also be tested in an analysis of only lean six sigma and six sigma cases. This would show where the specific benefits or detriments of statistical process are.

The SEM K models did not differentiate between the various levels of leadership. An SEM study that relates implementation outcomes to knowledge at differentiated leadership levels would be beneficial. This could develop constructs from identical question for each level of hierarchy and test if knowledge at one level was more important than others. Simmilarly firm ownership could be included, e.g. local owned, joint-venture, or foreign owned.

Free text responses of reasons for pursuing lean were captured in the first questionnaire. The responses categorised under employer introduction, other education, and required skill, imply less passion for improvement and excellence but are associated with external exposure to lean. These categories of people are expected to correlate less with a sound knowledge of true lean. In some cases greater interest may be sparked through these types of exposures to lean. The relationships between these categories and other variables could be investigated in future research.

Specific changes to the employee environments may help build habits and maintain momentum. The following construct for this was proposed from the existing variables.

- V048 Easy for suggestion/improvements
- V078 Program/Structure/Regularity
- V080 Standard work developed
- V098 Visual Systems

These variables were gathered but the construct was not tested; the variables were used in alternative constructs. The positive effects of the employee environment could be investigated by this or a similar scale.

The role of consultants in lean success or failure could be investigated. A further development of the consultant-based view of lean and its internal causality is beyond the scope of this work. Further SEM analysis could show what is overemphasised or underdeveloped by consultants. This would implicate how consultants should be used for lean success.

Key comparisons were made between management knowledge and management commitment. Management's knowledge (including their attitude toward learning and participation) had a stronger relationship with success. Further SEM exploration of what managers should commit to would be beneficial.

Free text responses to *V110 Significant negative outcomes* (Figure 290, p. 455) showed staff turnover as the highest occurring negative impact (26.6%, 17 of 64 responses tallied). Some participants suggested that the turnover was ultimately positive and others said it was negative, e.g. fear was created in other staff when resistant team members were removed. The exact effects require more investigation.

Researchers may be interested in the Tally of Text Responses table on page 447, and especially the Specific Text Response Variables (p. 456).

The relative lack of lean knowledge in New Zealand versus the United States of America could be investigated further. Additional survey questions could be added to test objectivity of responses and the distribution could be better controlled. A simplified survey could achieve a higher response rate. Additionally, the characteristics of New Zealand that explain the observed lack of familiarity in manufacturing were not specifically understood. The presence of more inhibitors of lean knowledge, less drivers for lean knowledge, or specific national characteristics could explain the effect.

Additionally, a question of principle versus practice could be investigated. The participants understanding and responses may not represent what their actual actions would be. That is, to what extent do practitioners who agree with a factor in principle (e.g. respect for people), neglect it in practice (e.g. actual involvement of all staff).

How to carry out lean education most effectively needs investigation. This includes how much learning can be accomplished without the doing (experience) in implementation. This is for developing first time success through the knowledge based-view of lean.

Besides knowledge and education, there are the individual characteristics and capabilities of those involved in an implementation. Although the simple capability variables tested did not rank highly, further research could uncover how management and staff capability are important. This could be accomplished for different business scenarios.

Finally, the benefits of lean knowledge and the detriments of the consultant and tools based approach were focused on in this work. Specific longitudinal case studies could further validate this work.

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11.4 Journal Publication

Pearce, A., & Pons, D. (2013). Implementing Lean Practices: Managing the transformation risks. *Journal of Industrial Engineering*, *790291*. doi:10.1155/2013/790291

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Research Article

Implementing Lean Practices: Managing the Transformation Risks

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Insightful implementation of lean is necessary for high-value manufacturing and is complementary to strategic decision making regarding manufacture. However lean can be difficult to implement in specific organisations. One of the difficulties is deciding which of the many lean tools to apply and when to apply them. A complicating factor is change management. Lean implementation is a transformational process and needs to support organisational development alongside process improvement. We develop a method based on risk management to identify which lean tools are most appropriate for a specific organisational setting. This permits the situational and contingency variables to be accommodated in the lean transformation. The method is demonstrated by application to a small manufacturing organisation with a high-variety low-volume business model. Thus it is possible, given contextual knowledge of the organisation, to predict which lean methods are most important in the situation. This enables the prioritisation of organisational effort towards lean methods that are relevant to the organisation at that particular time in its development.

1. Introduction

Lean is considered an essential attribute of a successful manufacturing endeavour [1]. The underlying principle of minimisation of waste for maximisation of productivity has become profoundly influential since being developed into the lean construct [2–4]. As lean has matured, it has been applied ever wider [5, 6]. This includes industries other than manufacturing and into manufacturing industries that were not natural early adopters. It is this latter category that is the focus of the present paper.

There is no doubt about the general relevance of lean principles. However the implementation in specific organisations is not straightforward and is not always successful. Sometimes this is because the principles were sound but the implementation failed [7–9], that is, a change management problem. But in the more general case, removing change management issues from consideration, there is still the difficulty of deciding which of the many lean tools to apply in the situation. This is important because lean includes many methods, and the relevance thereof is situationally specific. Implementing lean therefore requires some specific decisions, and the outcome has an element of risk: the implementation could succeed or fail. Unfortunately there are no specific tools for the selection and prioritisation of methods during implementation.

This paper explores the implementation of lean, with a particular focus on the choice of lean tools that are relevant to specific situations. We apply a risk management perspective, in the sense that the implementation of lean can be an opportunity for the organisation (if implementation succeeds) or a threat (failed implementation and wasted organisational effort, and resistance against future attempts). Thus we explore the intersection between strategic risk management and lean implementation. We show how risk considerations can be built into a method that can help identify which lean tools are most appropriate for a given situation. We close with a case study demonstrating the method for a small manufacturing organisation.

2. Existing Approaches to Lean Implementation

Lean implementation involves selecting appropriate tools from the lean arsenal to achieve process excellence. However

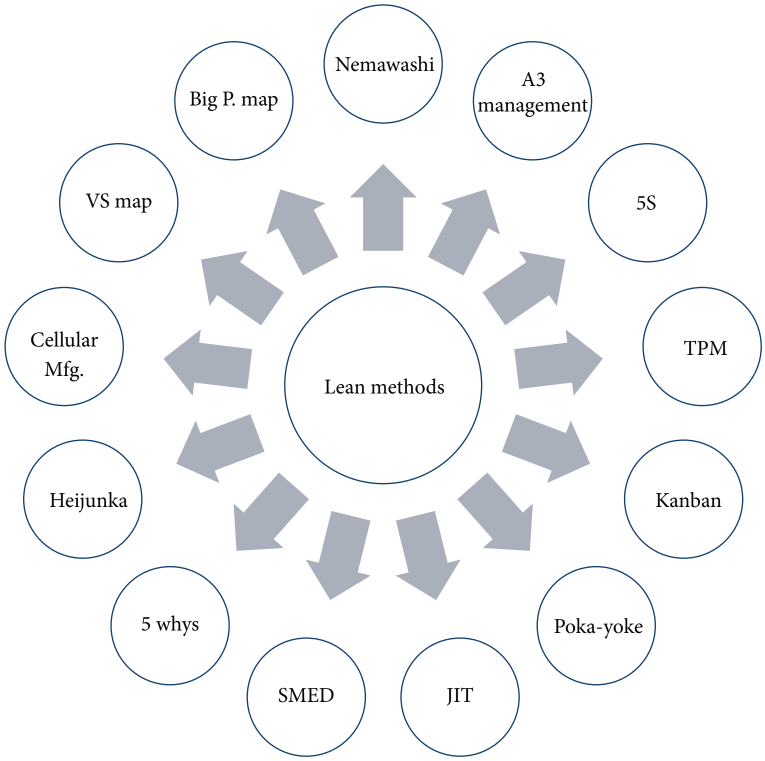


Figure 1: Lean methods or tools: a selection of some (not all) of lean methods indicating the importance of having a selection criteria and prioritisation method for implementation.

there is a danger of focusing overly on the tool benefit and striving for process excellence but neglecting the sustainability of the lean tool within that specific work culture. Every time a new method is implemented there is risk introduced to the organisation: both an opportunity and a threat. On the one side is the benefit of the technique and on the other side are the detriments. Relevant questions are:

(1) What is the benefit of the lean technique under consideration and how likely or difficult is it to achieve? (Is it worth doing this?)

(2) How do the usage of the lean technique and its benefits relate to the sustainability of the change intervention? (Would doing this have long-term benefits?)

In this paper we are particularly interested in the situational applicability of lean tools and specifically the organisational decision making that precedes the implementation of lean. There are three issues: which of the many lean tools to implement in a specific situation; how to make a balanced evaluation of the risks (opportunities and threats) for each candidate tool; and how organisational culture affects the success (or otherwise) of the change management implementation.

2.1. Lean Management, Its Principles, and Methods. Lean is a strategy developed for production improvement. It originated in the mass production setting of the automobile industry, specifically the Toyota Production System. It is primarily focussed on the minimisation of waste of any form [2, 3, 5, 7]. When wasteful action is eliminated the result is that less effort, space, and capital are required and lead time is reduced whilst quality increases and the cost of quality decreases [5, 10]. From its manufacturing roots, lean has subsequently expanded to business practice generally [11, 12]. Lean management is becoming the standard for systematic productivity improvement [1].

2.1.1. Lean Tools. Superficially, lean comprises a set of tools and techniques (kanban, 5S, TPM, SMED, etc.), and the naive implementation decision is simply which tools to implement. Figure 1 illustrates the multiplicity of tools available. Work has been done on the classification of tools [13–15] and the relevance of tools to specific wastes [16]. These go part way to addressing the problems with implementation, but situation specificity has not been achieved; that is, it is still not possible to identify which tools are most appropriate in which situation. Consequently practitioners frequently lack the means to make informed decisions about which tools to implement in their situation.

2.1.2. A Typical Implementation. A typical lean implementation involves an initial value stream mapping (VSM) which defines the journey of improvement. Next there is the organising of the house. This might involve flexible work systems and (especially) 5S (sorting, straightening, systematic cleaning, standardizing, and sustaining). Thereafter other specific tools are implemented as relevant. These include standard work, single minute exchange of dies (SMED), total productivity maintenance (TPM), and mistake proofing (Jidoka). Further advancements might involve supply and demand, through just in time (JIT) pull systems and Heijunka (level scheduling) [17]. Also relevant is the integration between lean and production planning and control systems such as materials resource planning (MRP). This is not always easy due to the lean emphasis on pull, whereas the reality is that many manufacturers benefit from hybrid production flow control [18]. Systems are being developed to operationalise this [19], though a detailed explanation is beyond the present scope.

Therefore weaknesses in a typical lean approach can be in fixation on tools as an end in themselves. This promotes isolated improvement rather than optimisation of the entire production system and an incomplete appreciation of the role of leadership for organisational development.

2.1.3. Organisational Culture and Change Leadership. In the context of organisational change we look for methods that will support sustainability, that is, obtaining enduring benefits. The decision to implement lean is typically a decision of senior management, that is, a top-down change initiative. While there are many models of the change management process [20–24], the process is not always as successful as intended [25, 26]. As change management shows, abrupt changes result in resistance [21, 27, 28]. At the deeper level lean is a culture, that is, a set of organisational attitudes, rather than a mere use of tools [29, 30]. The sustainability depends on organisational culture and the collective response to the change. Furthermore, many of the lean tools are sophisticated in their requirement for a particular type of culture, including strong intrinsic motivation at the shop-floor level for the processes (e.g., kaizen, 5S, quality circles, work cells, and six sigma). Thus implementing lean requires a change management process that fosters the outcomes, hence *change leadership* through coaching [21, 27] as opposed to merely directive top-down change. In a lean system the *respect for humans* principle is equally important as the elimination of waste [2, 11]. Lean is commonly associated with the latter and the respect for humans component is largely neglected. True lean involves a focus on the people of an organisation, creating a culture that empowers staff at all levels to make innovative changes that improve productivity by reducing wasteful action (*muda*). This creates dynamic and flexible learning organisations of emergent change [7, 31, 32]. Efficient and effective communication processes enable collaboration and consensus along with shared vision and engagement [7, 32]. In this way "respect for humans" works synergetically with and for "waste elimination." Neglecting the human component jeopardises the sustainability of the change and makes it difficult to reach the level of cultural excellence for continuous improvement [7, 8, 30]. A popular representation of this is the *iceberg model* of Hines et al. [7], with the lean tools, processes, and techniques being the visible component above the waterline, with the unseen supporting functions being strategy, leadership, and employee behaviour and engagement.

This introduces a time dimension to the implementation, since culture is not instant. Consequently it may be necessary to *build* that culture. Specifically, lean is implemented in stages over time, by selecting tools that are appropriate to the organisation at that point in time. It may be wiser to first implement simpler methods with the view of engagement and acceptance of staff as opposed to attempting to immediately introduce the more complex lean tools. These become small "wins" that build momentum and staff confidence [7, 27, 28]. Employees need to be engaged to support a difficult method (like JIT). Thus, even though certain lean tools may hold the promise of high returns, they may also be risky to implement. Failure could ruin future chances of success and engagement.

Implementation of lean is therefore an organisational strategy regarding the changing of culture over time, by the selective and progressive implementation of lean tools that are situational relevant for that organisation at that time, followed by further implementation later when the culture has caught up. Practitioners typically describe this deliberate temporal progression as the *lean journey* [7, 12, 33]. Thus the concept of continuous improvement (CI) applies not only to the technical operations but also the strategic implementation at organisational level. The residual difficulty is that of *deciding* which lean tools are relevant for the organisation at that point in its journey. This is a question to which we return, and in the next section we show how consideration of organisational *risk* can lead to a solution.

2.2. Risk Management. All ventures that an organisation undertakes have risk, that is, uncertain opportunity and threat. The risk management (RM) methods encourage a deliberate and integrated consideration of both these outcomes. Various standards have defined risk in the sense of both negative and positive aspects, for example, [34–36]. Other core concepts in the RM method are the partitioning of the problem into two variables, consequence and likelihood. Thus the analysis task reduces to determining first the magnitude of the outcome, which may be positive or negative, corresponding to opportunity or threat, respectively, and then the likelihood of that outcome. The magnitude of the outcome may be represented quantitatively or qualitatively. Likewise the likelihood may be quantified in a probability or expressed as a subject qualitative statement (very rare. . .almost certain). These two variables are then combined to give an overall score for the risk. If the variables are all quantitative then a simple product operation is used, but qualitative variables require a mapping process. The process is repeated for several scenarios under consideration and the RM method assists the decision making by identifying the scenario with the highest risk (or lowest as the case may be).

The risk management method is particularly effective for quantitative variables and has therefore found widespread adoption in engineering, finance (particularly insurance), and project management situations. Although the method as a whole claims to be applicable to strategic decision making even at the highest level of the organisation and examples of this are available [37], this is not a particularly well-developed capability of RM.

In lean implementation we are particularly focused on what is desirable in terms of lean success and sustainability and undesirable in terms of failure of the implementation.

2.3. Intersection between Lean Implementation and Risk Management. There has been some prior work at the intersection of these two bodies of knowledge. One line of enquiry, although perhaps not risk management per se, has been to identify critical success factors for lean implementation [7, 38–40]. Innovative frameworks and manufacturing techniques, for example, core competency based framework [41] and emergent manufacturing methods [42], have been applied to reduce specific "risks." The two methodologies have been compared [43] and applications in lean itself have been used to identify and treat uncertainties (risks) in construction projects [44, 45]. Processes including supply chain modelling have been used to support mitigation of risks [46–49]. The applicability of RM in selecting lean six sigma projects has been identified [50].

Regarding the specific question of how to manage the risks in the implementation of lean, there has been work on matching of lean systems strategy to risk identification, using a systems engineering approach [51], and use of project management methods [52]. It has been suggested to merge lean thinking and "high reliability" [53] to balance the nonbuffered, "fragile" nature of lean [54]. There is lack of methods to improve the reliability of lean implementation [55]. In summary, reviewing the literature we found little to no application of a standardised risk assessment to a lean implementation project.

Two other methodologies have some relevance. These are *Agile manufacturing* and *Theory of Constraints.* However neither of these have shown any major integration with risk management, though some movement has been made in that direction examples: for JIT see [56], for TOC see [57].

While the lean and risk management practices each have well-established literature, there is currently no integration between the two. This is despite the fact that the implementation of lean is full of risks: both the opportunities that the managers seek to capture, and the threats and failed implementations that too frequently result.

The purpose of this paper is to develop a methodology for assessing the risks—both the threats and the opportunities—of the lean methods. The particular area of interest is contextual decision-making: we wish to be able to better identify the lean tools that are relevant to specific situations. The area under examination is SME manufacturing firms, because lean is particularly difficult to implement in such organisations. This is worth attempting, for the potential to avoid failed lean implementation, the attendant wasted organisational effort, resistance against future attempts.

3. Approach

Our approach to this problem was to reconceptualise the decisions surrounding lean implementation as a risk management problem. We consequently developed a conceptual framework for treating lean in this way. From this we created a method for assessing the risks of lean practices. Importantly, this method is able to accommodate a specific organisational context. We then applied the method to a case study firm.

4. Results

4.1. Conceptual Model for the Integration of Risk and Lean. We start with the principles of risk management (RM) and lean. RM has a clear set of principles [35], whereas these are more tacit in lean. We therefore recast the contemporary understanding of lean into a set of principles and then compare and contrast these with those from RM.

The results are shown in Figure 2. The major difference in the function of risk management is to explicitly address uncertainty, whereas lean explicitly addresses wasted effort through the optimisation of flow. Nonetheless there is a clear fit between the principles. Both lean and risk management focus on "value". The risk approach protects value and lean supports this by focusing on providing customer value. Both are systematic and data driven. Both implementations are tailored to the organisation, take into account human and cultural factors, aim to be inclusive of the entire system (not compartmentalised or locally focused), and include all stakeholders in the processes. Both are dynamic and responsive to change and facilitate continual improvement of the organisation.

Next we compare the frameworks. Again, RM is more organised in this regard and already has a framework and we create a comparative one for lean. To do this we merge the lean iceberg model [7] and the 5 principles of lean [12]. The results are shown in Figure 3.

The lean concepts are synonymous to those of the risk management strategic process. The mandate and commitment of the framework is synonymous with management commitment, strategy, leadership, and alignment within the organisation. This is made more clear from the detailed definition in the standard [35] (cf. [7]). The cycle itself, design, implement, monitor, review, and continually improve, is a simple PDSA (or PDCA). This cycle came out of the quality and continuous improvement field [58, 59] which are consolidated in lean thinking. The five key principles of lean [5] can be shown to relate to the PDSA cycle although possessing specific meaning to lean thinking, that is, defining value and planning for the flow of value with as little waste as possible and the goal of perfection in view.

The final part of the conceptual model is creating an integrated process model. This is achieved by overlaying the lean processes on the risk management process; see Figure 4. The ongoing communication process indicated as key to good risk management is very much a part of continuous improvement and lean. Toyota developed particularly efficient and effective means of communication to allow consensus and collaboration throughout along with the engagement and input from all staff. Techniques such as A3 management, with the *catchball* process or *nemawashi,* are integral to the TPS and lean learning organisations; see [7, 32]. Establishing the context is synonymous to defining value from the customer viewpoint. The context in risk management strictly is both

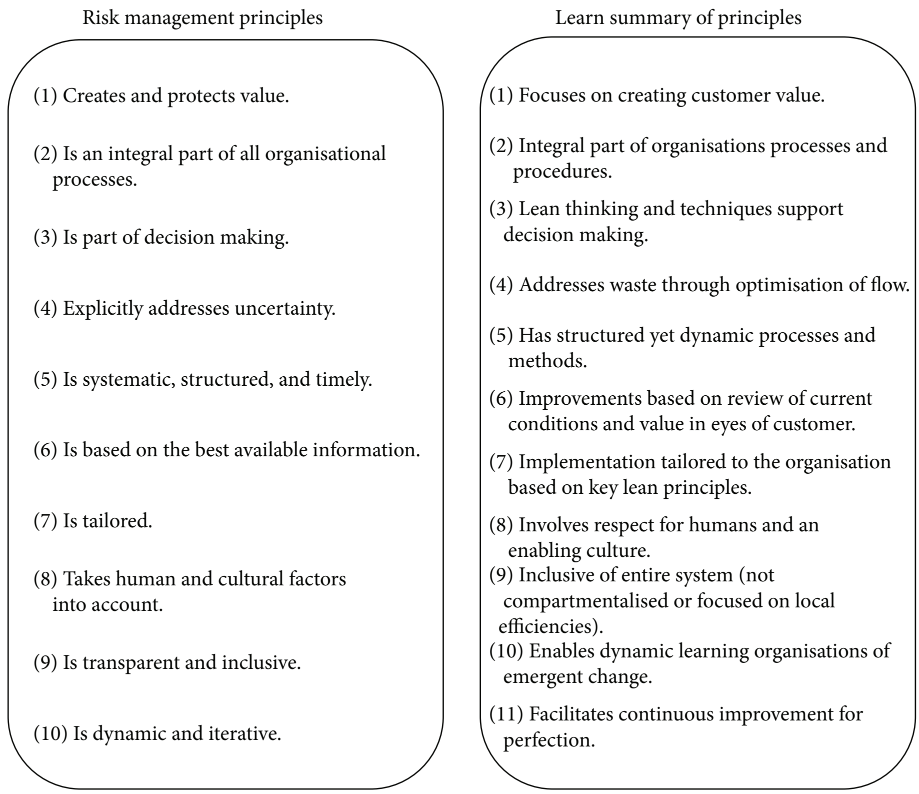


Figure 2: Principles of risk management [35] besides recast principles of lean thinking on the right, showing mutually supportive and complementary nature of risk management and lean management.

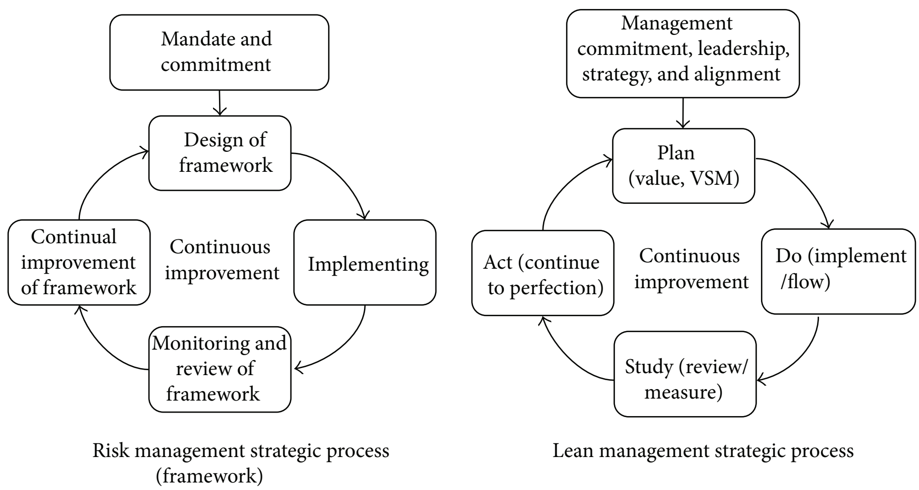


Figure 3: Risk management framework [35] compared with lean management.

internal and external looking and so in reality crosses with the mapping of the value stream. For simplicity sake we have included VSM in the risk assessment area, that is, looking at the current state and opportunities for improvements to get to a desired future state. In the assessment analysis step we have identified the 5 whys tool for root cause analysis (RCA). Other tools could similarly be used (e.g., Ishikawa fish bone diagram). Evaluation of risk has been overlaid with A3 management. This an A3 sheet for reporting and formulating ideas and passing into the communication process for consensus. Risk treatment is the appropriate application of various lean methods chosen through the assessment process. The PDSA cycle is built into the process for monitoring and review.

In some ways it is not surprising that the risk management approach matches with lean management, since both had roots in the quality and continuous improvement systems [4, 6].

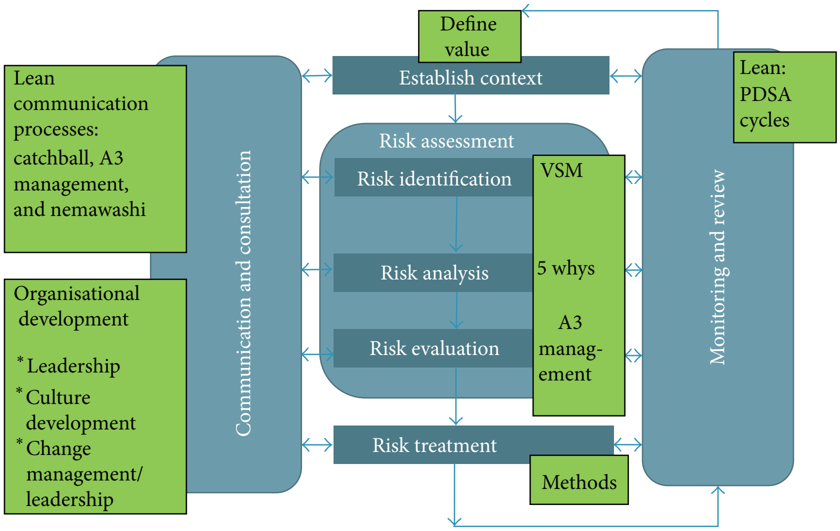


Figure 4: Lean processes overlaid on risk management process as per the ISO standard [35].

4.2. Developing a Mechanism for Implementation. Having achieved a broad conceptual integration of risk and lean, the next step is to develop an operational method, a mechanism for the application of RM to lean decision making. This needs to be suitable for practitioners. We assume that someone contemplating implementing lean has already acquired background knowledge of various lean tools (see Table 1) and focus our method on supporting the decision-making, identifying the factors that could be considered. We do this by following the risk management process taking particular care to represent the organisational factors, as these are known to be crucial for successful implementation. The results are shown in Table 1.

4.2.1. Process. Standard tools for the strategic scanning of risks are PESTEL and SWOT. These are for environmental scanning and identification of risks in the form of internal strengths and weaknesses and external opportunities and threats (hence SWOT) and may be characterised by political, economic, and other variables (hence PESTEL). The integration of these with strategic risk management has already been demonstrated [37]. The strategic risks are primarily qualitative, as opposed to quantitative, and hence a matrix mapping is appropriate (as opposed to quantitative treatment).

We therefore apply qualitative graphical techniques to represent the risk for lean implementation. We plot, as orthogonal variables, the impact of each specific lean tool, and the likelihood of achieving that impact; see Figure 5. In this regard we use *impact* where the RM method uses *consequence*, but the two are comparable. The impact is the effect on the organisation in regard to lean transformation.

The chart aids in identifying where initial wins or easy implementations can be targeted. Note that high likelihood (low difficulty) events can be critical even if the immediate impact is not high. This is because gaining small wins is particularly important at the outset of an implementation to ensure momentum and sustainability [7, 27, 28].

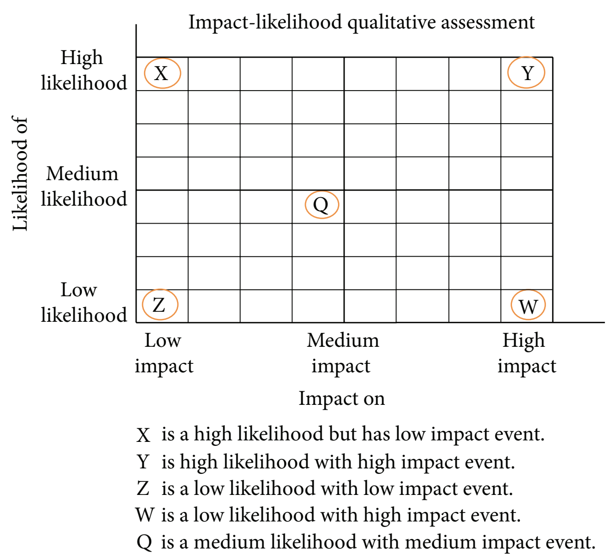


Figure 5: Likelihood-Impact qualitative assessment example plot.

In summary, we have established a method whereby the implementation of lean can be considered a type of risk, with potential positive and negative outcomes. We have created a method that is able to identify the risk associated with a specific aspect or tool of lean. The next section illustrates the application to a case study.

5. Application to Case Study

5.1. Characteristics of the Firm. The case study is a small to medium enterprise (SME) that is a make-to-order and design-build manufacturer specialising in complex parts and

Table 1: Summary of process for lean implementation risk management according to ISO 31000:2009.

Risk management process AS/NZS ISO 31000	Lean implementation Application
Set context	Lean systems reduce waste activities and increase value to customers, thereby increasing productivity and profitability. Internal context of resources and staff culture and sustaining the change. External context of market conditions.
Perform risk assessment by: (see (1)–(3))	
(1) identification of sources, areas, impacts, and events,	Lean methods have risk associated with their use, benefits, and detriments impacting various areas.
(2a) analysis to understand the risk its causes, sources, (see (2b)) and other pertinent factors,	Qualitative discussion of detriments or risks of sustainability of lean method (source) or entire lean implementation in context of the tools and consequences of tool use.
(2b) consequences and likelihoods, confidence sensitivity, and other pertinent factors,	Expert opinion (qualitative) is incorporated as charts. The chart shows our qualitative assessment of likelihood and consequence for various tools; refer to Figure 5.
(3) evaluation for assisting the decision making process including risk tolerance of parties.	In the context of organisational change we look for methods that will support sustainability. There is a decision from management (a mandate) to support lean to meet business goals but wisdom is required in the lean implementation for building a culture for sustainability. This involves selecting the right methods at the right time. It is necessary to get "wins" in the view of the staff up front. This is not necessarily the biggest wins but small wins to gain momentum and staff confidence. We cannot tolerate high risk even when high return is possible at the start of an implementation that is, where staff are not yet engaged to support a difficult method (like JIT). Failure could ruin future chances of success and engagement. Communication at the start of an implementation, is key to impart the vision and break down goals to give critical steps for change.
Prescribe treatment of risk To maximise benefits and minimise detriments, increase the positive and decrease the negative likelihood and consequences.	Treatments we prescribe in general cover the following: adequate communication with development of new identity for staff; prioritisation of time for business running and improvement activity; and prior conditions met adequately (including previous methods, training of and engagement of staff) for any methods implemented.

assemblies. It is representative of the many SMEs that are actively trying to decide which parts of lean are relevant to them and how to implement them. The firm ("SI") is based in New Zealand and has 20 employees. Typically production is of small to medium size runs, high-variety low-volume (HVLV). The firm possesses an advanced CNC equipped plant, has precision assembly capability, and takes pride in project management, that is, providing the full solution including concept and design development, build, commissioning, delivery, and after-sales support.

Historically lean has been the preserve of the large high-volume manufacturers typified by the automotive industry. However as the lean method has matured and spread to other industries, it has been applied to smaller and more specialised firms, like that considered here. Lean adoption is also driven by competitive pressure, particularly the opening of global markets and the resulting exposure to more efficient competitors. Therefore even the small firms have to consider how they preserve competitive advantage and deliver value to customers. These firms, being small, typically cannot afford to employ specialised staff for this purpose. They also have limited resources for implementing new programmes like this.

5.1.1. Strategic Mandate. In the case of this firm, the need to adopt lean was identified at board level, that is, was a strategic decision. To compete within the international market the firm needed to show the value of a local supplier by reducing lead time and manufacture costs and developing ability to handle demand variability (e.g., achieving flow and eliminating wasted effort including reducing run setups) as well as increasing quality. Lean methods can be used to treat these areas and therefore lean was considered a strategic priority.

At the strategic level the firm needed to treat key factors for success and sustainability of lean. These factors have been identified [7, 12, 27, 32, 60] and summarised in Table 2.

5.2. Evaluating Risk within the Lean Strategic Principles. One of the authors (AP) worked half-time for six months in the firm as part of a government-industry-university partnership. This provided the contextual knowledge for our analysis. We then took each of the strategic principle tools and evaluated, for this firm's context, the impact and ease of implementation (see Tables 3 and 4). We then plotted these on the risk chart; see Figure 7.

All the principles in this first set are of higher level and seen as critical to lean success and sustainability; however it is important to understand the challenges or level of difficulty faced. In our representative case we see particular areas of difficulty for SI around process flow, for example, flow and value stream analysis and application of pull systems. This

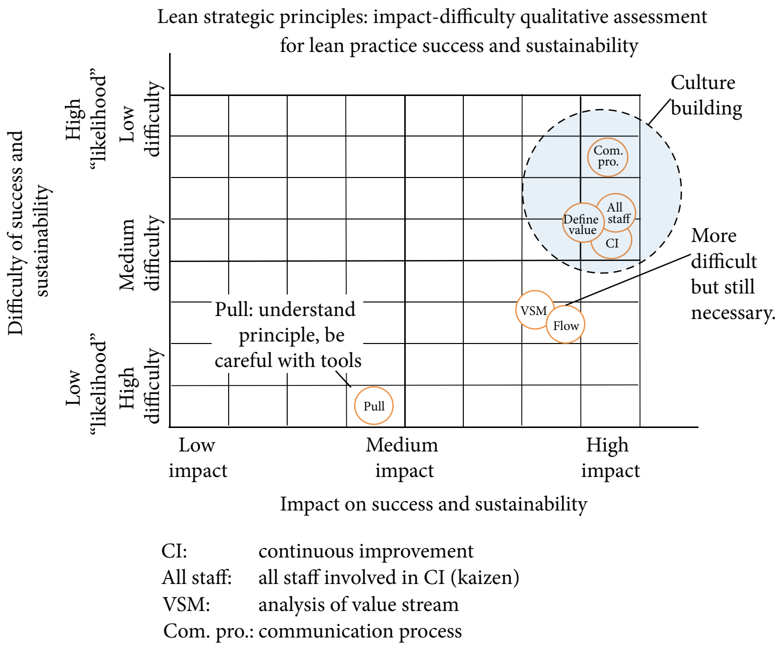


Figure 6: Strategic principles: lean key principles and higher order processes qualitatively assessed for impact and difficulty (likelihood) of success and sustainability (reference case SI).

Table 2: Lean risk treatment at a strategic level.

Change leadership	Leadership commitment with the vision and its communication for engagement of staff. The initial steps of change and ongoing "wins" for momentum of change. The development of a new organisation identity.
Managing internal resources	Physical, human (availability and capability), and financial resources need to be managed for amounts of training, learning, and implementing changes.
Managing external resources	Use of consultant (sensei) or other external resource for training.
Other factors	Market conditions and forecasts (risk), demand variability, and expected product mix (variety), among others.

is because of the make-to-order nature and complicated processes of their business. This is reflected in the Likelihood-Impact chart for these factors.

In Figure 6 we see the medium level difficulty but high impact of *defining value*, and having all staff involved in enterprise wide *continuous improvement*. Defining value is key to understanding what the customer desires and what wasted effort is that is, what should be eliminated through improvement. The communication process presents the vision of value and continuous improvement to all staff and allows for staff engagement and development of a learning organisation and hence also high impact. This suggests that the big wins for a make-to-order enterprise like SI would be in the culture excellence for continuous improvement and not so heavily in the process flow tools (although process improvement would occur as a result).

For the same reasons, value stream and flow are assessed as having only medium/high impact in the SI case. In contrast these would have high impact in a continuous production facility.

Pull is very difficult in SI's case and would need particular adaption as suggested in the table. SI may need to use pull of order to pull paperwork but push material to the process for flow. This would change where higher quantity production permitted and even temporary or isolated flow lines could be introduced.

5.3. Prioritising Lean Methods: SI Case Study. There are many different methods or tools of lean. These were each evaluated for the SI case, in a way complementary to the strategic principles. The likelihood and impact of these methods is plotted in Figure 8.

We do not attempt to justify the implicit judgements in Figure 7 whereby a particular method is given the impact and difficulty scores shown. Instead we suggest that this requires a contextual knowledge by the person performing the assessment. In this particular case the first author was seconded to the firm as part of the research project and spent considerable time learning the context in which Shamrock operated. The assessment presented as Tables 3 and 4 provide insight to the process.

The purpose here is to identify small wins (sometimes called "low hanging fruit") to increase chances of sustainability. Here the tools more applicable to the make-to-order business are featured in the *top right corner*. In contrast the tools for fine improvement of production efficiency,

Table 3: Strategic principles: lean key principles and higher order processes risk analysis table (reference case SI).

	Brief description	Benefits sought	Detriments/barriers Analysis of risk to sustainability of method or entire implementation effort	Treatments To maximise benefits, and eliminate or minimise detriments	Dependants
(A) 5 Strategic principles					
(1) Defining value	Lean begins with defining value from the customers point of view, that is, what is not value is waste to eliminate.	Gives clear strategic focus based on what the customer is willing to "pay for."	Requires survey of customers, may challenge traditional thought of what the company should be focusing on and therefore create conflict of identity and resistance.	Take to the required extent only—dependent on size and customer pool and current situation; for example, need to pull in more customers may need wider survey. Be prepared to develop new identity based on outcomes.	Voice of the customer.
(2) Process/value stream mapping (VSM) (difficult for Shamrock case)	Analysing of processes and waste there in by mapping current and the desired state. Complexity depends on need. In principle start with core process. This, together with defining value, sets the vision and course of action.	Gives a health check on now and identifies key processes or faults with a system. Gives future goal and direction.	Requires training and at higher levels all staff are involved. Can be simplified process where improvements and waste are more obvious but as more detail is required it is an involved and time consuming exercise. This is difficult in the Shamrock case due to the complicated jobbing processes that rarely repeat.	Training and prioritizing are key. Take only to the extent required for the current state of operations. Involve key persons from functional groups rather than all staff except where key to general training or staff identity development. At Shamrock initially concentrate on information flow (rather than cellular layout) and try to identify core processes for mapping and improvement.	Value must be clearly defined.
(3) Flow/one piece flow (difficult for Shamrock case)	Flow is a key concept to lean. It is seen ideal to approach one piece flow. Process flows should be made as visual as possible. Concepts like FIFO are introduced. Lean is "not trying to optimise the utilization of people and equipment but optimise the flow of material;" [2] includes information.	Reduces lead times, makes problems visible (bringing them to the surface) and supports quality at the source (see below under Tools).	Takes skill and training to understand flow and adjust the systems, for example, to make flow logical and visible. Typically involves changing of habits (e.g., FIFO) and takes rearrangement of physical and human resources (e.g., cells). Again this is difficult in the Shamrock case due to the complicated jobbing processes that rarely repeat.	Training in lean "flow thinking"—try reading The Goal [62] and Lean Thinking [12]. Promote to staff the reason why it is necessary and educate them about the benefits of flow. At Shamrock initially concentrate on information flow (rather than cellular layout) and try to identify core processes for mapping and improvement.	VSM done adequately.

Table 3: Continued.

	Brief description	Benefits sought	Detriments/barriers Analysis of risk to sustainability of method or entire implementation effort	Treatments To maximise benefits, and eliminate or minimise detriments	Dependants
(4) Pull (difficult for Shamrock case)	Process initiated by the customer's order "pull." The goal is to reduce batch size to approach one piece flow/JIT manufacture. See also "JIT" below.	Powerful in reducing waste and lead time. Inventory stores have all sorts of problems (space, quality, damage to stored goods, superseded parts, sales pushing on old stock).	Takes skill and training to understand properly. Promotes a lack of stability because buffers reduced—difficult for job shop and project based style organisations. Again this is difficult in the Shamrock case due to the complicated jobbing processes that do not repeat.	A progression from higher end of flow thinking to ensure flow is well developed. Can use buffers to support stability but not ideal. Use training of staff to overcome resistance (see Flow above). May need to use pull of order to pull paperwork and push material to flow.	Flow
(5) Journey to perfection	Continuous improvement via PDCA (plan, do, check, act cycle) of above steps.	Drives continuous improvement.	Needs Perseverance/sustainability	Build into processes (and culture). Target small wins at the beginning, maintain momentum, and leverage a new staff identity.	Value, VSM, flow
(B) Effective communication processes	Use of A3 management, nemawashi, and catchball—that is, concise reporting and feedback for consensus through simple and effective communication.	Consensus reached, staff engaged, vision shared. All contributing to the one goal and vision.	Development of the process is required e.g., training in A3 management. Sustainability and discipline required for regular but not excessive communication.	Training, persistence, building into procedures processes and regularity; try weekly meetings, tailor process to business situation.	
(C) All staff kaizen	Lean engages all staff in continuous improvement.	Emergent change from all adding up to significant change. Also positive culture.	Training and engagement of staff required. Meets resistance "not my job description."	Create new employee identity and train them in simple problem solving techniques for example, 5 Whys. Assess whether to remove negative influences among staff.	

Table 4: Methods: selection of lean and complementary methods risk analysis table (reference case SI).

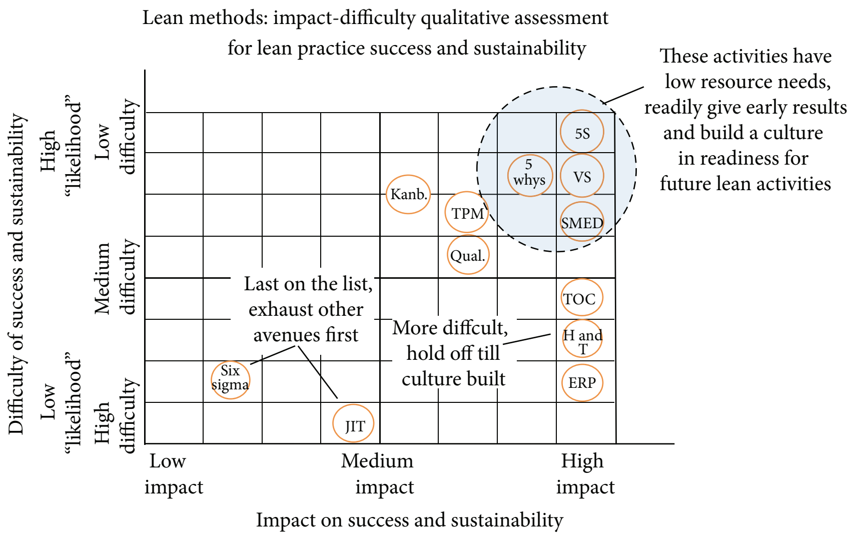
	Brief description	Benefits sought	Detriments/barriers Analysis of risk to sustainability of method or entire implementation effort	Treatments To maximise benefits, and eliminate or minimise detriments	Dependants
(A) Lean methods					
5S—sift, sort, sweep, standardise, sustain	General organisation, cleanliness, and maintenance.	General efficiency and basis for on-going improvements.	Training required (to low/medium level). Needs sustainability.	Develop new culture and expectation, use visual cues, develop new identity.	
5 Whys—root cause analysis	Basic root cause analysis tool; ask why 5 times. Get to the root of the issue so it does not repeat.	Simple effective way of doing root cause analysis and simple way to get people thinking about analysis.	Training required (to low level). Once trained if not used and ideas not acted on can be a negative experience, and reason for disinterest and failure in future.	Find a mechanism to drive root cause analysis of issues/events and ask why for daily activities. Implement suggestions to get momentum and show commitment (maybe even when not ideal).	
Visual systems	Emphasis on visualisation of flow and systems of control and reporting. Part of 5s, flow and all aspects of lean.	Visualises processes, makes waste visible. See other aspects, for example, 5s and Flow.	See other aspects, for example, 5s and Flow.	See other aspects, for example, 5s and Flow.	
Quality at the source, Jidoka, and Poka-yoke	Quality at source means control is given to the worker at the source of the issue—for example, on the production line. Jidoka is the respect for humans principle which includes mistake proofing (Poka-yoke) and in cases extends worker control to even shut down the production line.	Quality problems are not repeated, engagement of worker.	Training required (to medium/high level). If ignored, momentum/morale lost.	Make training a priority with key staff and then build training into daily activities. Systems for capturing ideas for poka-yoke and ensuring they get implemented.	
SMED—single minute exchange of dies (particularly beneficial to Shamrock)	Reduced setup time for machinery. Only essential internal setups made. External setups preferred to reduce downtime.	Setup time down, shorter runs possible and economically viable, enables reduced lead times and ultimately JIT. (particularly beneficial to Shamrock due to short runs).	Training required (to medium/high level). Downtime whilst working on improvements.	Make training and kaizen a priority with key staff and then build training into daily activities for others. Balance and make priorities clear (how much to spend on initiatives versus day job).	
Flexible work systems	Flexibility of employees and equipment preferred over complicated rigid or automated machinery.	Quick changeover and easily expanded systems, resources where required	Training of staff and their engagement required (to medium level). Loss of specific staff roles and responsibilities.	Communication process for change and benefits. Develop new identity.	

Table 4: Continued.

	Brief description	Benefits sought	Detriments/barriers Analysis of risk to sustainability of method or entire implementation effort	Treatments To maximise benefits, and eliminate or minimise detriments	Dependants
Total productive maintenance (TPM)	Ensuring machines maintained to secure against unnecessary downtime and catastrophic failure—should incorporate continuous improvement also.	Less downtime. Health and safety improved.	Training of staff and their engagement required (to medium/high level). Skill of staff.	Select right people, train in appropriate skills, and give understanding to staff (build new identity).	
Kanban	Simple tool for replenishment/pull system. Typically a card (e.g., kanban card) but could be a bin or another identifier that flags for replenishment and specifies details (supplier, qty, location). One rule of kanban is to review its size (i.e., reduce the buffer towards one piece flow as part of continuous improvement).	Links separated processes together for pseudoflow where ideal flow is not possible.	Needs setup and organisation.	Visual systems and no shortcuts help to enforce the documented procedures.	5S
Just in time (JIT) manufacture. (difficult for Shamrock case)	Goods arrive just in time for processing or assembly.	WIP and lead time down, quality up.	Lack of stability because buffers removed. Process takes much planning, training, and teething during implementation. Negative results to culture possible during teething. Again this is difficult in the Shamrock case due to the complicated jobbing processes.	Suggested to hold finish goods only (in production situations) or push and flow used. Both at pull of order by customer. Must be well prepared for implementation: Staff training for their understanding and engagement, other process prepared as much as possible, ready for on-going teething internally and with suppliers. Use pilot and positive staff member willing to try. Consider carefully before implementation.	Flow achieved, needs Heijunka (level scheduling)
Heijunka (level schedule) & takt time (pulse) (difficult for Shamrock case)	Level scheduling is smoothing demand—we include also takt time here which is easiest understood as average demand in time (e.g., 2 parts per minute or two quotes per day, two invoices per week).	This is key to enable JIT/one piece flow effectively without excessive idle time or overtime in production.	Difficult in Shamrock scenarios due to high fluctuating demand, for example, job shops make-to-order and project based manufacture.	Level selling/marketing. Keeping buffer of finished goods to help (but not parts throughout entire system). Understand in terms of the specific business and where it is most applicable there.	Flow achieved

Table 4: Continued.

	Brief description	Benefits sought	Detriments/barriers Analysis of risk to sustainability of method or entire implementation effort	Treatments To maximise benefits, and eliminate or minimise detriments	Dependants
(B) Complimentary Methods					
Business systems software and production control technology e.g., ERP (particularly beneficial to Shamrock)	Interactive IT databases which may incorporate logarithms for scheduling and financial management.	Information collaborative reduced data entry and codification of knowledge. Particularly useful at Shamrock because of high administrative demands on complicated processes and customer requirements	Typically implementation times, culture change, and customisation requirements all extensive. Can be expensive and restrictive.	Ensure the solution is right for your environment (many may be better with simple kanban planning boards and replenishment systems). Get well prepared and ensure to have the right skill, resources, and technical support on hand.	
Theory of constraints (TOC)	TOC is in itself a standalone process improvement technique with its own overarching philosophy. It identifies bottlenecks "capacity constrained resources" that need to be targeted to improve flow.	Great for training and supporting flow thinking. Read the book The Goal [62]	Does not implicitly include philosophy and culture of staff engagement and empowerment—typically consultant driven and not sustained as a standalone.	Incorporate for flow training and use as suitable as a complimentary method but be careful not to affect overarching strategy.	
Six sigma	Six sigma is in itself a standalone process improvement technique with its own overarching philosophy. It is most well known as a statistical method of process analysis and improvement, Six sigma can be applied as a tool within a lean philosophy.	Fine improvement of processes after basic obvious waste eliminations is made.	High level training and highly time consuming exercise to use. Workers can become too narrowly focused on statistical tools when simple problem solving is all that is required.	Use and train only as required in the meantime; use VSM and 5 whys for early results.	Other simpler methods exhausted.



VS: visual systems
Qual.: quality tools—quality at the source, Jidoka, and Poka Yoke
SMED: single minute exchange of dies/reduced setups
TPM: total productive maintenance
Kanb.: kanban
JIT: just in time manufacture
H and T: Heijunka (level schedule) and takt time (pulse)
ERP: business systems software
TOC: theory of constraints

Figure 7: Methods: selection of lean and complementary methods with a qualitative assessment of impact and difficulty (likelihood) of success and sustainability (reference case SI).

for example, six sigma and JIT, are in the bottom left. These were assessed as particularly difficult to implement in this particular situation, and the benefits would be limited. Implementation of TOC thinking would be more beneficial than six sigma or JIT in this case. Kanban is positioned in the middle, and while (in this situation) it may not be relevant for pulling production, it could still be useful for ordering consumables. Managers and business owners at SI broadly endorsed the validity of this analysis of the situation.

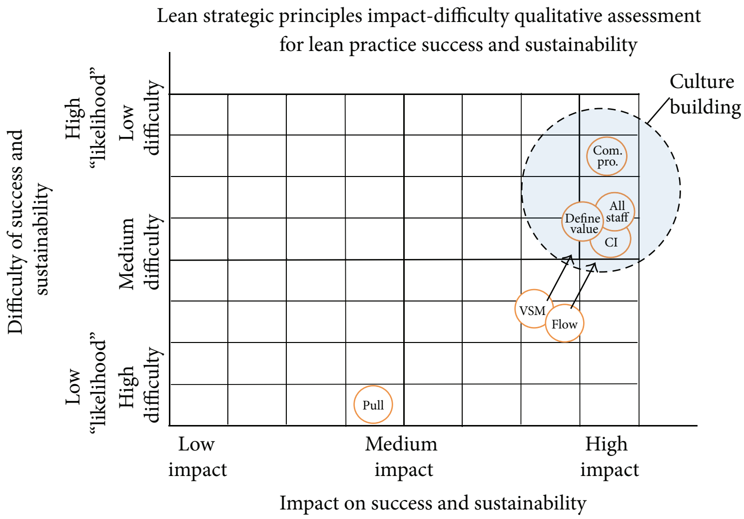
5.4. Implications for SI. Of interest is the high impact of ERP in SI's case. This is something difficult to implement but if implemented right could have great effect. This is particularly because at SI production was partially being constrained by flow in the office. ERP implemented right would simplify quoting, planning, purchasing, and general data entry requirements which are identified as serious bottlenecks at SI (more so than specific physical production processes). It could also give other benefits such as business reporting. SI has much to benefit in understanding the holistic nature of its systems and the interaction between the factory and office processes.

Resource constraints are significant in SMEs and determine how much the organisation can achieve at any one time. In this particular case SI had just embarked on an ERP implementation that is somewhat separate from an enterprise wide lean journey. Because of the difficulty of ERP implementation our suggestion would be to hold off all other lean initiatives (except for some higher order principles) until ERP is well achieved and the resources are freed to focus on other lean implementation activities. This also implies that if they had a clean slate and had not begun implementing ERP it may have been more beneficial to consider some of the simpler tools first. This could have benefited them with further staff engagement and built culture excellence and staff engagement before implementing ERP with its higher requirements on resources and perceived level of change.

5.4.1. Beyond Production. We have noted that lean has been applied effectively beyond manufacturing or production businesses. Although SI is a manufacturing business we observed they had many gains to be made in their administration centre (hence a high priority for ERP). Whether or not the physical transformation of goods took place in their own workshop there was much waste to be eliminated in their office. These lean office gains illustrate the competitive advantage of lean beyond manufacturing businesses.

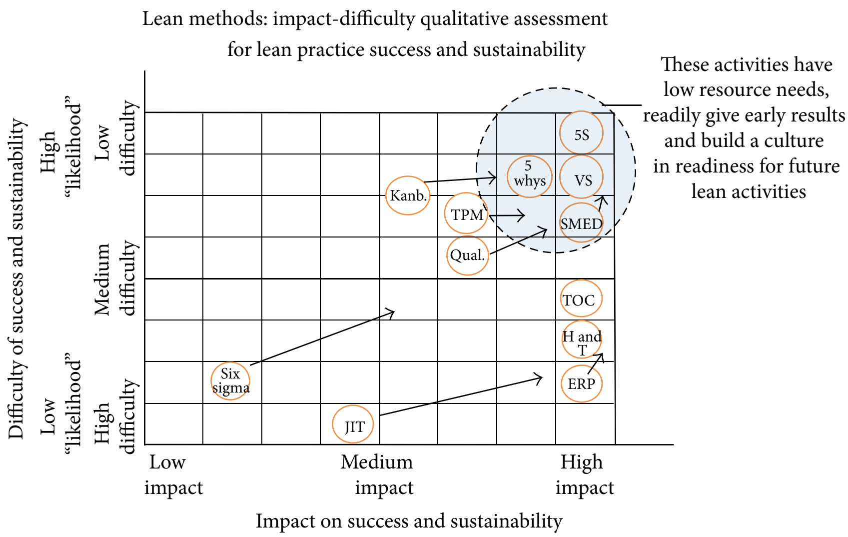
5.5. Application to Other Manufacturers. The implications would be similar for other make-to-order, design to order, job shop SMEs, although ERP requirements may drop where products do not demand a lot of records and data entry or process control (as compared with SI's high tech and precision engineering customers).

For firms of higher production (e.g., low-variety high-volume) we would see more relevance in the emphasis on



CI: continuous improvement
All staff: all staff involved in CI (kaizen)
VSM: analysis of value stream
Com. pro.: communication process

(a)



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H and T: Heijunka (level schedule) and takt time (pulse)
ERP: business systems software
TOC: theory of constraints

(b)

FIGURE 8: Methods and strategic principles for alternative (volume manufacture) scenario: indicative qualitative assessment of impact and difficulty (likelihood) of success and sustainability for "higher" production volumes as depicted by arrows.

process flow principles and tools. We have illustrated these and other likely changes by placing arrows overtop of the previous charts; see Figure 8.

6. Discussion

6.1. Outcomes: What Has Been Achieved? This work encompasses lean thinking and methods, lean implementation, organisational change, and risk management. Exploring the literature at the intersection between risk management and lean transformation we found no application except for piecemeal usage of methods and aspects of lean loosely tied to risk. There was little evidence of risk management and lean implementation being integrated by practitioners.

The present work makes several novel intellectual contributions. The first is methodological, in that it demonstrates a way to integrate risk management into decision making when implementing lean. This method makes the detriments (the threat component of the risk) more explicit and therefore amenable to treatment. The method achieves a high level of integration between the two management methods. We did this by comparing lean management with risk management as codified in the ISO standard [35] and developing a common framework with lean.

A second contribution is that the method provides a way to explicitly identify the organisation difficulty of implementing lean practices. This is important, because although these organisational difficulties have previously been identified in general terms (e.g., the lean iceberg model), it has up to now been difficult to determine how those apply to specific situations. Thus variables that were once general situational variables (or contingency factors to use the change management term) can now be included in the decision-making. The method, while not specifically providing a temporally phased approach to lean implementation, encourages the decision-maker to explicitly evaluate which lean methods are relevant to the organisation at the time under consideration.

The third contribution is that we have piloted a method for applying lean to organisations other than high-volume manufacturers. In particular, the method was developed in a challenging type of organisation: an SME involved in high-variety low-volume manufacturing. This type of organisation has otherwise found it difficult to implement lean, as seen in the late adoption. The method and the case study bring out implications and provide solutions that could be relevant to other types of organisation too. The case study showed that it is possible, given contextual knowledge of the organisation, to predict which lean methods are most important in the setting. This enables the prioritisation of organisational effort, something that is relevant to all organisations but particularly to SMEs with their limited resources for such endeavours.

A fourth contribution is that we have now built another conceptual component in a model for high-value manufacturing. This is of national strategic importance to small countries like New Zealand, whose manufacturing industries cannot easily compete with other countries that have low labour costs and high production volumes. We suggest that intelligent implementation of lean is necessary for high-value manufacturing and is complementary to strategic decision making regarding manufacture [3] and environmental considerations [61], among others.

6.2. Implications for Practitioners. For practitioners, that is, those managers in organisations that are considering what parts of lean to implement, the primary implication is that they should not only focus on the high impact lean methods but also consider a staged approach. We recommend they deliberately select lean methods that will build lean culture through small wins and staff engagement, before progressing to more overly lean methods. Lean implementation involves a transformation of the organisation, and initially the journey (i.e., the human dimension of the change process) is as important as the destination.

In making the decisions about lean, our suggestion is that managers consider applying the method given here, by evaluating the impact of each of the lean principles and tools and the difficulty of implementing them *in that specific organisational context.* We suggest that the organisational context is very important, and that the analysis is best done by someone who has deep understanding of how the organisation operates. At the same time it is also important that the analyst understands the capabilities of the various lean principles and tools. In this paper we have only identified these by name, as a full description would overwhelm the present paper. However we recommend practitioners gain the necessary lean knowledge by consulting one of the many excellent texts or employing an expert.

Another implication for practitioners is that the method we propose here is closely aligned to the risk management method. Consequently there should be no impediment to including the lean risk assessment alongside other risk management practices. Alternatively, if the risk management framework [35] is not already part of the organisation's practices, then we would suggest that consideration should be given to exploring that too, since it is not much more effort than to do so. The management approaches are complementary and mutually supportive having synonymous principles, framework, and process.

6.3. Limitations and Implications for Further Work. A limitation of this work is that the case study was more of a cross-sectional rather than longitudinal design and on only one firm. This naturally limits the external validity (limits the ability to generalise to other situations). It would be interesting to apply the method to a firm or multiple firms over time to assess how well the predicted lean methods actually performed and how decision making priorities adjust in time.

Another limitation is that the analyst needs both contextual knowledge of the firm and knowledge of the lean methods. We have explicitly identified that need in our recommendations to practitioners. It would be interesting to know just how much knowledge practitioners really have about lean. The root of failed implementations of lean might be ignorance, which would also limit our method. It would be interesting to do a widespread survey of the extent of lean knowledge and check whether that causes poor implementation.

7. Conclusions

The objective of this work was to explore how risk management methods are applicable to and supportive of lean implementation success. Risk analysis and management are critical to all serious decision making processes. However there has been little to no documented application or study of risk management in the lean implementation field. We have shown that it is possible to integrate risk management and lean management. We further developed a qualitative method where lean tools may be prioritised for a specific organisational setting. We applied this method to a case study. The case study provided implications for similar high-variety low-volume manufacturers as well as alternative operation modes (e.g., low-variety high-volume manufacturing, service organisations, and administration). The ongoing efficacy of lean tools and methods is very much dependent on the situational variables of the organisation. We believe that each aspect should pass through a risk assessment and analysis of some kind to determine treatments necessary. Our approach focused on treating lean failure by prioritising the tools that not only will deliver performance gains but also are culture building.

Authors' Contribution

All authors contributed to the conceptual and intellectual development of the ideas in this work and to their expression in this paper. Antony Pearce performed the detailed lean risk assessments and spent the time embedded in the case study firm.

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12. Appendix 1—Investigation Materials

12.1 Status of New Zealand Industry Tables and Charts

12.1.1 New Zealand Earnings and Employment Survey (QES) - QEX, Filled Jobs by Industry (ANZSIC06), Quarter two 2011

	Filled Jobs 2011 Quarter 2	Percentage of Total Jobs
Professional, Scientific, Technical, Administrative and Support Services	227,700	13.5%
Health Care and Social Assistance	200,100	11.9%
Manufacturing	193,800	11.5%
Retail Trade	181,400	10.8%
Education and Training	156,000	9.2%
Accommodation and Food Services	113,400	6.7%
Construction	112,000	6.6%
Wholesale Trade	98,900	5.9%
Arts, Recreation and Other Services	98,700	5.9%
Public Administration and Safety	90,700	5.4%
Transport, Postal and Warehousing	79,000	4.7%
Financial and Insurance Services	49,700	2.9%
Information Media and Telecommunications	33,400	2.0%
Rental, Hiring and Real Estate Services	27,900	1.7%
Forestry and Mining	12,200	0.7%
Electricity, Gas, Water and Waste Services	11,500	0.7%
Total All Industries	1,686,500	100.0%

Figure 192 New Zealand Earnings and Employment Survey (QES) - QEX , Filled Jobs by Industry (ANZSIC06), Quarter two 2011 (Statistics NZ, 2011)

12.1.2 New Zealand Production A/C, GDP (Production Measure) Constant Price, Annual (Annual-Mar) in Billons of NZD (New Zealand Dollars)

Prodn A/C, GDP & GDE, Market Price, Curr & Const. Price,

	Current Prices		Constant Prices	
	GDP - product measure	GDP - expenditure measure	GDP - product measure	GDP - expenditure measure
2009	185,561	185,220	134,650	137,265
2010	187,802	187,355	133,759	138,313
2011	..	198,043	135,904	140,961

Figure 193 New Zealand GDP 2009 – 2011 in Billions of NZD (Statistics NZ, 2011)

Prodn A/C, GDP (Prodn Measure) by HOTP Ind, Const. Price, Annual (Annual-Mar)

Service Industries	$	96,620
Finance insurance	$	39,285
Goods Producing	$	24,992
Community and Personal Services	$	16,512
Manufacturing	$	16,393
Transport storage and	$	14,096
Primary Industries	$	10,386
Retail trade	$	9,989
Wholesale trade	$	9,841
Government	$	6,789
Agriculture	$	6,774
Construction	$	5,678
Fishing forestry and	$	3,455
Electricity gas and water	$	2,670

Prodn A/C, GDP (Prodn Measure) by OECD Ind, Const. Price, Annual (Annual-Mar)

Agriculture, Fishing and	$	8,704
Mining, Manufacturing, Electricity Gas and Water	***$***	***20,972***
Wholesale and Retail,	$	33,664
Government	$	23,238
Bank Service Charge	$	7,015
GST, Import Duties and	$	10,984
All Industries	$	131,625

Prodn A/C, GDP (Prodn Measure) by Aggregated Ind, Const. Price (Annual-Mar)

Real Estate and Business Services	$	20,427
Business Services	$	12,083
Finance and Insurance	$	9,976
Wholesale Trade.	$	9,841
Ownership of Owner-occupied Dwellings	$	9,152
Communication Services	$	8,438
Property Services	$	8,355
Retail Trade	$	8,099
Health and Community Services	$	7,778
Agriculture	$	6,774
Transport and Storage	$	6,213
Construction	$	5,677
Food, Beverage and Tobacco Manufacturing.	$	5,512
Central Government Administration and	$	4,998
Education	$	4,653
Unallocated	$	3,970
Electricity, Gas and Water Supply	$	2,670
Machinery and Equipment Manufacturing	$	2,338
Wood and Paper Products Manufacturing	$	2,267
Cultural and Recreational Services	$	2,162
Accommodation, Restaurants and Bars	$	1,944
Metal Product Manufacturing	$	1,918
Personal and Other Community Services	$	1,909
Local Government Administration	$	1,787
Forestry and Logging	$	1,761
Petroleum, Chemical, Plastic and Rubber	$	1,587
Mining	$	1,471
Printing, Publishing and Recorded Media.	$	1,140
Non-metallic Mineral Product Manufacturing	$	697
Textile and Apparel Manufacturing	$	556
Furniture and Other Manufacturing	$	420
Fishing	$	194
Sum of Manufacturing	***$***	***13,708***

Figure 194 Various measures of GDP by industry Source- National Accounts - SNA 1993 – SNC (Statistics NZ, 2011)

12.1.3 Lean Risk Analysis Additional Tables

See following pages for definition and qualitative analysis of Lean principles and methods.

	BRIEF DESCRIPTION	BENEFITS SOUGHT	DETRIMENTS/ BARRIERS **Analysis of Risk to sustainability of method or entire implementation effort**	TREATMENTS **To maximise the benefits, and eliminate or minimise the detriments**	DEPEN-DANTS
(A) 5 Strategic Principles					
(1) Defining Value	Lean begins with defining value from the customers point of view i.e. what is not value is waste to eliminate	Gives clear strategic focus based on what the customer is willing to "pay for".	Requires survey of customers, may challenge traditional thought of what the company should be focusing on and therefore create conflict of identity and resistance.	Take to the required extent only – dependent on size and customer pool, current situation e.g. need to pull in more customers may need wider survey. Be prepared to develop new identity based on outcomes	Voice of the customer
(2) Process/Value Stream Mapping (VSM) (Difficult for Company A Case)	The analysing of the process and waste there in by mapping the current and the desired states. Complexity depends on need. In principle start with the core process. This, together with defining value, sets the vision and course of action.	Gives a health check on now and identifies key processes or faults with a system. Gives future goal and direction.	Requires training and at higher levels all staff are involved. Can be simplified process where improvements and waste are more obvious but as more detail is required it is an involved and time consuming exercise This is **difficult in the Company A case** due to the complicated jobbing processes that rarely repeat.	Training and prioritising is important. Take only to the extent required for the current state of operations. Involve key persons from functional groups rather than all staff except where key to general training or staff identity development. At Company A initially concentrate on information flow (rather than cellular layout) and try to identify core processes for mapping and improvement.	Value Must Be Clearly Defined
(3) Flow/One Piece Flow (Difficult for Company A Case)	Flow is a key concept to Lean. It is seen ideal to approach one piece flow. Process flows should be made as visual as possible. Concepts like FIFO are introduced Lean is "not trying to optimise the utilization of people and equipment but optimise the flow of material" (Ohno, 1988)–which includes	Reduces lead times, makes problems visible (bringing them to the surface) and supports quality at the source (see below under Tools).	It takes knowledge, skills, and training to understand flow and how to adjust the system e.g. to make flow logical and visible. Typically involves changing of habits (e.g. FIFO), and takes rearrangement of physical and human resources (e.g. cells). Again this is **difficult in the Company A**	Training in lean "flow-thinking" – Try reading The Goal and Lean Thinking. Promote to staff the reason why it is necessary and educate in the benefits of Flow. At Company A initially concentrate on information flow (rather than cellular layout) and	VSM done adequately

	information		**case** due to the complicated jobbing processes that rarely repeat.	try to identify core processes for mapping and improvement.	
(4) Pull (Difficult for Company A Case)	Process initiated by the customer's order "pull". The goal is to reduce batch size to approach one piece flow/JIT manufacture – See also "JIT" below	Powerful in reducing waste and lead time. Inventory stores have all sorts of problems (space, quality, damage to stored goods, superseded parts, sales push on old stock)	It takes knowledge, skills and training to understand properly. Promotes a lack of stability because buffers reduced - Difficult for job shop and project based style organisations. Again this is **difficult in the Company A case** jobbing processes that do not repeat.	A progression to a higher end of flow thinking. Ensure flow is well developed first. Can use buffers to support stability but not ideal. Use training of staff to overcome resistance (see Flow above). May need to use pull of order to, pull paperwork and push material to flow.	Flow
(5) Journey to Perfection	Continuous Improvement via PDCA (Plan, do check act cycle) of above steps	Drives continuous improvement	Needs Perseverance/Sustainability	Build into processes (and culture). Target small wins at the beginning, maintain momentum, and leverage a new staff identity.	Value, VSM, Flow
(B) **Effective Communication Processes**	Use of A3 Management, Nemawashi and catchball – i.e. concise reporting and feedback for consensus through simple and effective communication	Consensus reached, staff engaged, vision shared. That is, all contributing to the one goal and vision.	Development of the process is required e.g., training in A3 management. Sustainability and discipline required for regular but not excessive communication	Training, persistence, building into procedures processes and regularity, try weekly meetings, Tailor process to business situation.	
(C) **All Staff Kaizen**	Lean engages all staff in continuous improvement.	Emergent change from all adding up to significant change throughout. Also a positive culture.	Training and engagement of staff required. Meets resistance "not my job description"	Create new employee identity and train them in simple problem solving techniques e.g. 5 Whys	

Figure 195 Strategic Principles: Lean Key Principles and Higher Order Processes Risk Analysis Table (Reference Case SI.).

	BRIEF DESCRIPTION	BENEFITS SOUGHT	DETRIMENTS/ BARRIERS **Analysis of Risk to sustainability of method or entire implementation effort**	TREATMENTS **To maximise the benefits, and eliminate or minimise the detriments**	DEPEND -ANTS
(A) **Lean Methods**					
5S – Sift, Sort, Sweep, Standardise, Sustain	The general organisation, cleanliness, and maintenance. Often used as the first tool for lean implementation.	General efficiency, and basis for on-going improvements.	Training required (to low/medium level). Needs sustainability.	Develop new culture and expectation, use visual cues, develop new identity.	
5 Whys – root cause analysis	Basic root cause analysis tool, ask Why 5 times. Get to the root of the issue so it does not repeat .	Simple effective way of doing root cause analysis and simple way to get people thinking about analysis.	Training required (to low level). Once trained if not used and ideas not acted on can be a negative experience, and reason for disinterest and failure inn future.	Find a mechanism to drive root cause analysis of issues/events and ask why for daily activities. Implement suggestions to get momentum and show commitment (maybe even when not ideal).	
Visual Systems	Emphasis on the visualisation of the flow, the systems of control, and reporting. Part of 5S, flow and all aspects of Lean.	Visualises processes, make waste visible- See other aspects e.g. 5S and Flow	See other aspects e.g. 5S and Flow	See other aspects e.g. 5S and Flow.	
Quality at the Source, Jidoka and Poka Yoke	Quality at source means control is given to the worker at the source of the issue - e.g. on the production line. Jidoka is akin to the respect for humans principle which includes mistake proofing (Poka-Yoke) and in cases extends worker control to even shut down the production line.	Quality problems are not repeated , Engagement of worker,	Training required (to medium/high level). If ignored - momentum/morale lost.	Make training a priority with key staff and then build training into daily activities Systems for capturing ideas for poka-yoke and ensuring they get implemented.	
SMED – Single Minute Exchange of Dies (Particularly Beneficial to Company A)	Reduced setup time by ensuring only essential internal setups made. External setups preferred to reduce down time.	Setup time down, shorter runs possible and economically viable, enables reduced lead times and ultimately JIT. **(Particularly Beneficial to Company A due to short runs)**	Training required (to medium/high level). That means a skill requirement and time out of production whilst working on improvements.	Make training and kaizen a priority with key staff and then build training into daily activities for others. Balance and make priorities clear (how much to spend on initiatives versus day job).	
Flexible Work Systems	Flexibility of employees and equipment preferred over complicated rigid or automated machinery.	Quick changeover and easily expanded systems, resources where required	Training of staff and their engagement required (to medium level). Loss of specific staff roles and responsibilities.	Communication process for change and its benefits. Develop a new identity,	
TPM - Total Productive	Ensuring machines maintained to secure against unnecessary	Less down time. Health and safety improved.	Training of staff and their engagement required (to medium-	Select right people, train in appropriate skills, and give	

Maintenance	downtime and catastrophic failure – should incorporate continuous improvement also.		high level). Skill of staff.	understanding to staff. (Build new identity)	
Kanban	Simple tool for replenishment/pull systems. Typically a card (e.g. kanban card) but could be a bin or other identifier that flags for replenishment and specifies details (supplier, quantity, and location). One rule of kanban is to review its size (i.e. reduce the buffer towards one piece flow as part of continuous improvement).	Links separated processes together for pseudo flow where ideal flow is not possible.	Needs setup and organisation.	Visual systems and no short cuts help to enforce the documented procedures.	5S
JIT - Just In Time Manufacture (Difficult for Company A Case)	Goods arrive Just in time for processing or assembly.	WIP and lead time down, quality up.	Lack of stability because buffers removed. Process takes much planning, training and teething during implementation. Negative results to culture possible during teething. Again this is **difficult in the Company A case with make-to-order** jobbing processes.	Suggested to hold finished goods only (in high-volume situations) or push and flow used (for high- variety low-volume).But either at the pull of order by the customer. Must be well prepared for implementation: Staff training for their understanding and engagement - other process prepared as much as possible - ready for on-going teething internally and with suppliers and customers. – Use pilot and positive staff member willing to try. Consider carefully before implementation.	Flow achieved, needs heijunka (level scheduling)
Heijunka (level schedule) & Takt time (pulse) (Difficult for Company A Case)	Level scheduling is smoothing demand - We include also Takt time here which is easiest understood as average demand in time (e.g. 2 parts per minute or two quotes per day, two invoices per week)	This is key to enable JIT/one piece flow effectively without excessive idle time or overtime in production.	Difficult in Company A scenarios due to high fluctuating demand e.g. job shops make to order and project based manufacture.	Level selling/marketing. Keeping buffers of finished goods to help (but not parts throughout entire system). Understand in terms of the specific business and where it is most applicable there.	Flow achieved

(B) Complimentary Methods					
Business systems software and production control technology e.g. ERP (particularly beneficial to Company A)	Interactive IT databases which may incorporate logarithms for scheduling and financial management.	Information collaborative reduced data entry and codification of knowledge. **Particularly useful at Company A because of high administrative demands on complicated processes and customer requirements**	Typically implementation times are long, there is a significant culture change, and there are customisation requirements. These systems can be expensive and can be restrictive.	Ensure the solution is right for the environment (many may be better with simple kanban planning boards and replenishment systems). Get well prepared and ensure to have the right skill, resources and technical support on hand.	
TOC – Theory of Constraints	TOC is in itself a standalone process improvement technique with its own overarching philosophy. It identifies bottlenecks "capacity constrained resources" that need to be targeted to improve flow.	Great for training and supporting flow thinking. Read the book *The Goal* (Goldratt & Cox, 2004).	Does not implicitly include philosophy and culture of staff engagement and empowerment – typically consultant driven and not sustained as a standalone.	Incorporate for flow training and use as suitable as a complimentary method but be careful to not affect overarching strategy.	
Six-sigma	Six-sigma is in itself a standalone process improvement technique with its own overarching philosophy. It is most well known as a statistical method of process analysis and improvement, Six-sigma can be applied as a tool within a lean philosophy.	Fine improvement of processes after basic obvious waste eliminations is made.	High level of training required and a highly time consuming exercise to use. Workers can become too narrowly focused on statistical tools when simple problem solving is all that is required.	Use and train only as required in the meantime, use VSM and 5 whys for early results.	Other simpler methods exhausted.

Figure 196 Methods: Selection of Lean and Complementary Methods Risk Analysis Table (Reference Case SI).

12.2 Methodologies for Lean Research

Various methods of research are available to the lean field as discussed in this document. Each of these methods has their prospective pros and cons. It is the researcher's job to use their knowledge and intuition to select from these techniques and use them in varying degrees to provide the best outcome for a project given its particular constraints (time, financial, geographical, ethical or otherwise. A review of research methods for lean allowed formation of an efficient yet grounded study.

The purpose of the review was:

1. To explore research methods in use, particularly those used in the realm of production improvement, and specifically lean.
2. The review of statistical methods for the research.
3. The preparation of a research methodology for the greater study.

Relevant articles were selected from lean and similar topics of research. A study of statistics was also conducted. A selection of the varying research methods was summarised. The topical research categories reviewed were:

Literature Research	Statistical Method
Interview Method	Confirmation Bias
Survey Approach	Topic Importance
Modelling Techniques	Ethics
Case Studies	Other Techniques
Computer Modelling	

Of this critique, the discussion of bias is most specific to the questionnaire method utilised, and so is included here. This section summarises two works (Nickerson, 1998; MacCoun, 1998).

12.2.1 Confirmation Bias

Confirmation bias is relevant to this research. This speaks mainly of a bias to select or give more weight to data and information that supports or confirms a certain notion or hypothesis. The bias may come from an early or preconceived concept or preference; it may be a result of the way a question is asked and the type of information that it leads to. Confirmation bias as a concern for this research is not about a deliberately selected bias as an attorney gathers evidence for a one sided defence or a debater for their side of the argument. The concern is ignorance, i.e. that a researcher might unintentionally select data and/or information that supports their case and not equally important data and information that point to the contrary (Nickerson, 1998; MacCoun, 1998). Nickerson (1998) differentiates between deliberate and spontaneous case building.

> *"The line between deliberate selectivity in the use of evidence and unwitting molding of facts to fit hypotheses or beliefs is a difficult one to draw in practice, but the distinction is meaningful conceptually, and confirmation bias has more to do with the latter than with the former."*
>
> (Nickerson, 1998)

It is important to understand that this form of bias exists. A researcher needs to avoid both personal seeking of and giving undue weight to evidence that supports a bias. The researcher must be careful not to lead others to an unwilling bias, e.g. by the way an experiment or survey is designed. To aid this purpose some types of bias are presented as by Nickerson (1998) along with a brief explanation.

1. Hypothesis—Determined Information Seeking and Interpretation—the seeking of information that mainly or only supports the belief or hypothesis that is predetermined.
2. Preferential treatment of evidence supporting existing beliefs—This is not merely rejecting but rather not being as receptive of countering information to the point of ignoring or discrediting such.
3. Looking only or primarily for positive cases—i.e. giving undue weighting to positive cases i.e. cases which affirm the hypothesis even when they don't have a vested interest in the case.

4. Overweighting positive confirmatory instances—i.e. focusing on one that fits
5. Seeing what one is looking for—That is a preconception leads one to see that thing, for example a concept about someone having negative traits will cloud one from seeing their positive traits and amplify mentioned negative traits.
6. The Primacy Effect and Belief Persistence—The initial formulation of a belief from information acquired early tends to carry continued weight in one's consideration.
7. Own-Judgment Evaluation —This refers to overconfidence in one's judgement that lead to the atrocities of genocide.
8. Judicial Reasoning—This is very close to belief persistence but as happens in the court of law as the judge or jury develops their mental model of a case starting with the initial presentations. The tendency that the model be driven by the initial evidence rather than the later leads for bias.
9. Conservatism—Overconfidence and Theory persistence in science—This is speaking of science and the tendency to give an existing theory the precedence above other possibilities. This is a case of bias leading to persisting false beliefs. As Nickerson (1998) states

   > *"[Unfortunately in science] the usual strategy for dealing with anomalous data is first to challenge the data themselves. If they prove to be reliable, the next step is to complicate the existing theory just enough to accommodate the anomalous result too."*

In their conclusion MacCoun (1998) states that evidence shows that the effect of confirmation bias is small in science, i.e. due to proper methods and design. However as would be recognised there have also been many cases of continued belief in fallacy throughout history; for example the continual persistence that the world was flat.

Four norms of practice that are widely considered as been required for sound scientific research are:

Universalism—requiring that judgements be made by criteria that are impersonal.

Communism (communalism)—requires the sharing of scientific information publicly.

Disintredness—a stipulation of objectiveness required by investigators.

Organized scepticism—requiring a communal scrutiny to new findings in the scientific community. This involves review, replication, and testing opposing hypotheses.

These four norms were presented by Robert Melon in 1973 (MacCoun, 1998). Science of course is much different to legal fields and it is trusted that a scientist will act honourably such that truth will win out (MacCoun, 1998).

Bias may exists as strategy-based error, i.e. an error in research method due to some ignorance. Or where a mental contamination occurs as a person uncontrollably adds bias.

Scientists must be aware of the desire to believe a certain outcome. Another trap is an inability to simultaneously process conflicting information i.e. information that would confirm a truth of a hypotheses along with information that would deny it. Further persons can be prone to seek positive results tending to a positive test strategy or positivity bias. Again a person my introduce bias due to the reference frame i.e. as one forms an imaginative frame around a concept, e.g. from prior suggestion, that frame becomes the condition for that person to confirm that bias. Nickerson (1998) discusses that the way people are educated to justify what they believe installs a biasing tendency and that bias is compounded by inadequate seeking of knowledge. Nickerson (1998) continues:

> *"Our natural tendency seems to be to look for evidence that is directly supportive of hypotheses we favor and even, in some instances, of those we are entertaining but about which are indifferent. We may look for evidence that is embarrassing to hypotheses we disbelieve or especially dislike, but this can be seen as looking for evidence that is supportive of the complementary hypotheses. The point is that we seldom seem to seek evidence naturally that would show a hypothesis to be wrong and to do so because we understand this to be an effective way to show it to be right if it really is right."*
>
> *"The knowledge that people typically consider only one hypothesis at a time and often make the assumption at the outset that that hypothesis is true leads to the conjecture that reasoning might be improved by training people to think of alternative hypotheses early in the hypothesis evaluation process."*

And MacCoun (1998) adds some examples:

> *"Examples that might influence the interpretation of research findings include: (a) using fallacious deductive syllogisms (e.g. affirming the consequent, denying the antecedent), (b) failing to adjust for non-independence among evidentiary items, (c) confusing correlation with causation, and (d) relying on heuristic persuasive cues (e.g. appeals to an investigator's prestige or credentials)."*

Corrective Practices

It is important to briefly discuss opportunities for correction of bias.

<u>Debiasing:</u> Some forms of debasing include the increasing of incentives for accuracy, holding persons accountable, enhancing outcome feedback, providing inferential training, decomposition of task, and encouraging alternative hypotheses consideration.

<u>Strong Inference and Condition Seeking</u>: Strong inference strategy is when the researcher's method includes the study of not one single hypothesis but many competing hypotheses. Condition seeking, rather than being theory driven is data driven; an approach where a researcher deliberately searches (from the procedure for a finding) for the many conditions that are necessary or sufficient for the finding.

<u>Peer Reviewing, Replication, Meta-Analysis, and Expert Panels:</u> There is a strong reliance on peer review and related analysis or reanalysis of work by others. MacCoun (1998) sees this as an indicator of being

“unwilling to place all our faith in training and socialization as means for guaranteeing unbiased judgments by individual researchers” and discusses that research “demonstrate that under a wide variety of circumstances, collective decision making will significantly amplify individual bias, rather than attenuate it. When a bias exists homogeneously across participants then the bias is most likely to be amplified. Conversely the greatest potential for bias correction is through constructive conflicts.

These practices for correction where presented by MacCoun (1998) but what are the chances of being protecting oneself against such? Again Nickerson (1998):

> *“Is it possible to put a belief that one holds in the balance with an opposing belief that one does not hold and give them a fair weighing? I doubt that it is. But that is not to say that we cannot hope to learn to do better than we typically do in this regard.”*

As compared to MacCoun’s (1998) closing statement:

> *“Scientific practice is clearly very different. As expressed by Merton.S (1973) norms, citizens in our culture have very clear role expectations for scientists; if one claims the authority of that role, one is bound to abide by its norms or risk misleading the public… The evidence suggests that the biases are often subtle and small in magnitude; few research consumers see whatever they want in the data. The available evidence constrains our interpretations even when intentions are fraudulent and the stronger and more comprehensive the evidence, the less wiggle room available for bias. Systematic empirical research methods have played a powerful role in identifying biased research interpretation and uncovering its courses.”*

Unfortunately people are prone to bias, thankfully scientific practice such as observing Melon’s norms – Universalism, communism, disinterestedness (objectiveness) and organised scepticism can help. However in general a researcher needs to guard themselves from misdirection and unwilling bias with these types of objectivism and proper consideration. Thus Nickerson’s notion, a researcher can hope to learn to do better. (Nickerson, 1998; MacCoun, 1998)

12.3 Case Study—Examples of Work

This section contains examples of early stage implementation planning by the learning lean practitioner.

12.3.1 Company B Production System Implementation Plan

The Company B Production System (CBPS)[188] is Company B's approach to ensuring productive manufacturing. The goal is to facilitate continuous improvement of process towards perfection. ***The way is by creating a culture that empowers staff to make innovative changes that improve productivity***. Rather than spending effort solving problems as they occur, effort is to be invested in constant improvement such that problems do not occur and the company moves towards perfection.

Not as simple as Process Improvement but Change Management to a Lean Operation

1) Develop the Vision and Strategy (PESTEL/SWOT ANALYSIS)
2) Crisis (Establish Urgency—most important)
3) Form a Guiding Coalition from the team
4) Implement Change (Target Low Hanging Fruit)
5) Communicate the Wins
6) Begin to develop a culture
7) Consolidate gains, produce more change

Formalise/Time Bound/Anchor in culture/Maintain constant crisis with vision and need for change.

Background Operations

1) Production Manager (Antony)
    a. Own learning and Preparation for Education of other staff into Lean thinking and methodologies for (1) below
        i. Develop the Vision and Strategy (PESTEL/SWOT ANALYSIS)
        ii. Develop basic systems and tools for Visual Planning and KPI's
        iii. Identify Key Processes and Map the current state
        iv. Mapping of Preliminary future states of processes (include other staff)
        v. Exploring Robust New Processes, forms and planning methodologies (including technology on hand and available for purchase where appropriate)
    b. Overall goal is not to merely set up systems but to educate and facilitate staff development such that Company B as an enterprise can function and continue to develop further towards perfection beyond Antony's[189] time there.

[188] The CBPS is directly comparable to the TPS or Toyota Production System as a foundation from which came Lean Manufacturing however the CBPS is logically adapted to suit Company B specifically.

[189] The Production Manager and more specifically change agent.

Implementation Plan

1) Education of staff
    a. Senior management Session + read The Goal and Lean thinking
    b. Senior Staff
    c. All Staff
2) Create the Crisis and Develop the Vision- Set the Scenario (Work increase due to earthquake how can we cope?)
3) Presentation to staff as whole
    a. Present the vision—hand it to the staff, get their buy in
    b. Use "OFI" Form as tool
        i. "The OFI (Opportunity for Improvement) form exists to formalise and force recognition of the front line staff suggestions.
    c. Form a "Guiding Coalition" to positively support change
        i. Work with key enthusiastic, bright staff in key areas
        ii. Educate and empower the frontline people
            1. Empower/Delegate/Give Responsibility//Give Control
            2. Create an environment of learning and lateral thinking
    d. Try to get an immediate case study going to show enforce
    e. Advertise "Wins" (use Planning Board)
    f. Check progress: P D C A Deming cycle
4) Establish Regular Meetings to
    a. To review Production
    b. To track progress toward perfection
    c. To train staff and develop culture
    d. Use "A3 Management"
    e. Can double for health and safety etc.
    f. Conduct Staff reviews to develop engagement
5) 5S Implemented/Stressed
6) Waste Defined
7) Look at Flow in Steelwork Plant (can we do a flow line for beams?)
8) … Keep going… continual PDCA

12.3.2 Improvement Engineer Programme Sign Up Form

The following form was developed as part of a culture change in regards to staff identity for a lean implementation. The purpose was to promote and engage staff in taking initiative to improve their areas of work in line with business goals.

Company B Improvement Engineer

(Registration Confirmation form)

As Toyota has "The Toyota Production System[190]" Company B has The Company B Production System (CBPS). The CBPS is Company B's approach to ensuring productive manufacturing. The systems goal is continuous improvement towards perfection. The way is by creating a culture that empowers staff to make innovative changes that improve productivity. Rather than spending effort solving problems as they occur, effort is to be invested in constant improvement such that problems occur less frequently as the company moves towards "perfection". The target of perfection is a moving one but short and simple we must continually adapt. If we are not changing, i.e. if we are not improving we are being left behind. Yes, we may currently be busy and have much potential work on the horizon but the competition is at the door and we don't know how quickly things in the economy can turn and markets can change. We need to "stay ahead of the game." For this we request our staff to take the title of Improvement Engineer and will provide training for this role as part of regular company activities.

Staff Meetings and "OFI" Form

The regular staff meetings and the OFI (Opportunity for Improvement) form exists at Company B to force recognition of the front line staff initiatives. At its most basic, it is about improvement suggestions. Examples of OFIs are concerns about health and safety, a quality complaint, or suggestions for new plant or a new ways of doing things. The use of the form and the group discussion helps force the company to acknowledge, record, review, and respond to suggestions of an opportunity otherwise left unnoticed or ignored. These forms are currently available in the Health and Safety folder.

Guideline for Suggestions: From Our Place of Work

In principle, the changes we suggest should be directly from "our frontline", our place of work. It is possible to suggest improvements in others work i.e. others training and outside help sometimes necessary. However we should focus our activities on our own field of expertise, our place of work i.e. what you "struggle with" day to day. Is there a better way of doing what you are doing?

The Goal of Improvement: Increasing Value Adding Activity

The goal of change in the CBPS is to Increase the amount of activity that adds value to the customer and decreasing amount of activity that does not add value to the customer, i.e. decreasing waste. We must be customer focused and ask what the customer wants.

Improvement Engineer	Manager (Responsible to record in training register)
Name: Signature: Date:	Name: Signature: Date:

[190] Company B's Production System is based on Lean Manufacturing, a leading manufacturing thinking developed from Toyota's Production System.

12.4 Risk Management Standard—Further Details

12.4.1 Management Framework AS/NZS ISO 31000

The framework provides the foundation for the embedding of a risk management culture and assists in application of the process. The top of the framework is mandate and commitment required to drive and sustain the effort. It then drives the design of the framework which is implemented, monitored, and reviewed for continual improvement.

The framework design incorporates the organisations internal and external contexts, establishing of policy and accountability. Additionally there is the integration, the embedding of risk management into the organisations processes and allocation of appropriate resources e.g. human, technical and personnel development. Further, there is requirement for communication and reporting mechanisms internally and externally. It is apparent that the standard writers are conscious of a change process required for establishing risk management in organisations.

12.4.2 Risk Management Process AS/NZS ISO 31000

The process is specified to be *"integral",* "*embedded in culture and practic*e" and *"tailored to the business processes of the organization"* (AS/NZS ISO 31000, 2009, p. 13). Similar to the process reviewed earlier it includes: Establishing the context, risk assessment, and treatment and on-going monitoring and review with communication and consultation. The risk assessment itself is broken into:

1. Identification of sources, areas, impacts, and events.
2. Analysis to understand the risk its causes, sources, consequences and likelihoods, confidence sensitivity and other pertinent factors,
3. Evaluation for assisting the decision making process including risk tolerance of parties.

Treatment options for modifying the risk(s) can be proposed, reviewed, and decided upon after an appropriate understanding of the risk case is gained. Treatments are decided on in terms of costs, benefits, and detriments. Naturally, all stake holders should be involved where possible. Note the on-going emphasis on communication, monitoring, and review.

The process and activities should be traceable. Records and recorded processes and procedures provide a basis for continual improvement, similar to standard procedures in lean itself (Liker, 2004).

13. Appendix 2—Additional Results

13.1 Experiment One

13.1.1 Second Tier Outcomes and Ancillary Results

In this section are secondary outcomes of experiment One. For secondary outcomes of experiment Two, see page 435.

SEM of Knowledge to Holistic View and Methods

SEM (Figure 197) tested the relationship between lean as methods to knowledge. The hypothesis was:

Hypothesis: Relationship Knowledge->Holistic is much stronger than Knowledge->Methods. The relationship between Knowledge->Methods is insignificant, describing little of the variance in Methods.

Accepting this supports the following understanding: Lean as tools and processes, new systems and ways make up the baseline of the definition of lean at low knowledge levels, the understanding of lean as a holistic system comes forth at high knowledge levels. The latent construct Methods was formed from variables V051 Tools and Processes and V056 New Systems and Ways.

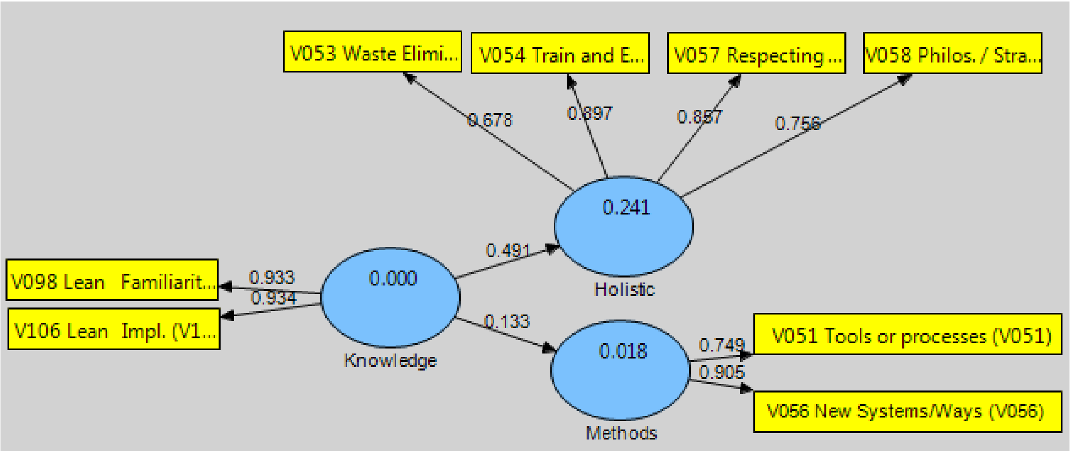


Figure 197 Path Loadings -SEM of Knowledge to Holistic View and Methods SMART PLS OUTPUT (Data Set 193 cases 100% Complete)

Quality for the model was acceptable and as expected for these exploratory purposes (see Figure 199, p. 379 and discussions of criteria, p. 182). The model Shows only a very weak relationship between Knowledge and Methods (R^2 =0.02<<0.2 and path β=0.13) much weaker that Knowledge to Holistic Methods (R^2 =0.24>0.2 and path β=0.49). All paths are significant with t-value > 1.96, p < 0.05 (Figure 198, p. 379). ***Hypothesis is accepted.***

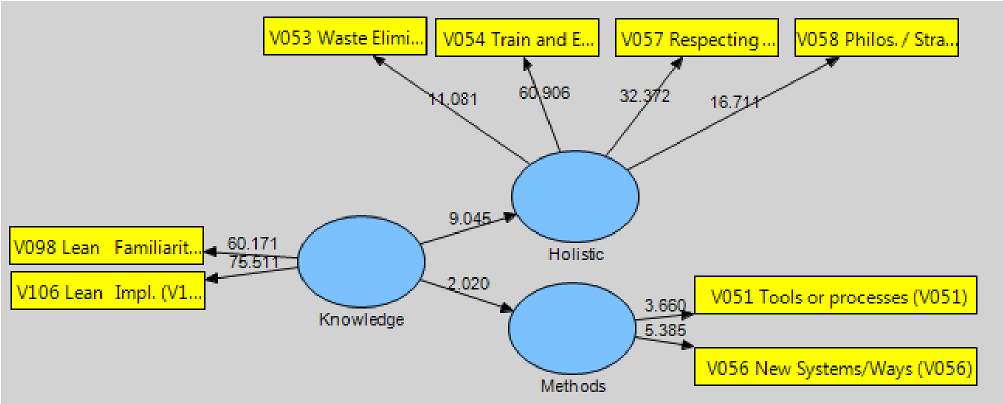


Figure 198 Bootstrapped - SEM of Knowledge to Holistic View and Methods SMART PLS OUTPUT. All paths t-value > 1.96, p < 0.05 (Data Set 193 cases 100% Complete, Bootstrapped 500 time)

Outer Loadings

	Holistic	Knowledge	Methods
V051 Tools or processes (V051)			0.75
V056 New Systems/Ways (V056)	0.00		0.91
V053 Waste Elimin. (V053)	0.68		
V054 Train and Empower (V054)	0.90		
V057 Respecting People (V057)	0.86		
V058 Philos. / Strategy (V058)	0.76		
V098 Lean Familiarity (V098)		0.93	
V106 Lean Impl. (V106)		0.93	

Reliability

	AVE	Composite Reliability	Cronbachs Alpha
Holistic	0.64	0.88	0.81
Knowledge	0.87	0.93	0.85
Methods	0.69	0.82	0.57

Goodness of Fit

	R Square	Communality
Holistic	0.24	0.64
Knowledge		0.87
Methods	0.02	0.69
Average	0.13	0.73

Gof	*0.31*

Gof >0.31 recommended

Fornell - Larcker Criterion (Fornell & Larcker, 1981)

Latent Variable Correlations compared with √(AVE)

	Holistic	Knowledge	Methods
Holistic	**0.80**		
Knowledge	0.49	**0.93**	
Methods	0.40	0.13	**0.83**

Bold = √(AVE)

Criterion= √(AVE) >factor loading

Cross loadings

	Holistic	**Knowledge**	**Methods**
V051 Tools or processes (V051)	0.26	0.08	**0.75**
V056 New Systems/Ways (V056	0.38	0.13	**0.91**
V053 Waste Elimin. (V053)	**0.68**	0.29	0.37
V054 Train and Empower (V054)	**0.90**	0.47	0.35
V057 Respecting People (V057)	**0.86**	0.45	0.29
V058 Philos. / Strategy (V058)	**0.76**	0.33	0.29
V098 Lean Familiarity (V098)	0.46	**0.93**	0.12
V106 Lean Impl. (V106)	0.46	**0.93**	0.13

Figure 199 Validation Tests - SEM of Knowledge to Holistic View and Methods

Significant Differences (ANOVA Analysis)

Statistically significant differences ($P<0.05$) were found in 68% of the questions. 91% of the understanding variables and 33% of the implementation variables showed these differences (see Figure 230, p. 404 for full ANOVA tables). Differences were observed in 91% of the variables when using finer intervals e.g. comparing small extent with very great extent rather than aggregated high and low, but that methodology was weaker statistically.[191] Most of the significant differences found were across all three grouping variables: familiarity, experience, and competitive advantage of lean. These differences are presented in ANOVA table, Figure 200. The differences imply the top missing concepts in people's lean knowledge. These were the missing or inadequately stressed concepts from industry, education, and training. The variables were ordered by statistical significance based on lean familiarity grouping. Discrepancies in ranking by competitive advantage variable are highlighted.

Lean giving workers training and empowerment (V054) showed the most significant differences. This variable appears to describe the major difference between those with higher and lower knowledge and experience in lean as well as those who consider lean a lower advantage. Effect for lean familiarity was $F(1,336)=80.7$, $p<0.0001$, for implementation experience was $F(1,232)=24.7$, $p<0.0001$ and for competitive advantage was $F(1,324)=54.7$, $p<0.0001$. The matter of training and empowerment is reflective of the respect for people principle, which is ranked the second most significant by familiarity ($F=34$) and third by experience ($F=16$). Effects by competitive advantage ranked respect for people lower, the equivalently of fourth equal. For lean as waste elimination (V053), new systems and ways of doing things to improve productivity (V056) and respecting people (V057) were "4th equal" by competitive advantage ($F = 20.8$, 18.8 &18.4). Taking lean as the business philosophy correlated stronger by competitive advantage ($F=30.7$) than the respect for people principle ($F=18.4$). Increasing familiarity will develop the understanding and the terminology of the principles of lean. This accounts for larger effects by familiarity. Whereas for gaining competitive advantage, it is strongly indicated that lean needs to be the business philosophy and strategy for success. Lean needs regularity and focus was highly ranked by all (3rd or 4th) grouping variables, familiarity gave $F(1,346)=56.6$, $p<0.0001$.

[191] This method is weaker statistically. The safer results of high low are reported here.

			Across Full Available Likert Range														
			Familiarity (V098) Low cf. High					**Implementation Experience** (V106) Low cf. High					**Competitive Advantage** (V062) Low cf. High				
Variables																
Variables Ordered by Lean Familiarity	Relati-onship +ve / -ve	Number That Found p<0.05	df Error	F	p	0.05=>P>0.01	0.01=>P	df Error	F	p	0.05=>P>0.01	0.01=>P	df Error	F	p	0.05=>P>0.01	0.01=>P
Train & Empower (V054)	+ ve	3	356	80.7	0.0000		X	232	24.7	0.0000		X	324	54.7	0.0000		X
Needs regularity and focus (V059)	+ ve	3	346	56.6	0.0000		X	224	6.6	0.0108	X		318	24.0	0.0000		X
Respecting People (V057)	+ ve	3	331	54.4	0.0000		X	221	20.3	0.0000		X	308	18.4	0.0000		X
Waste Elimin. (V053)	+ ve	3	363	51.2	0.0000		X	234	4.6	0.0330	X		331	20.8	0.0000		X
Philos. / Strategy (V058)	+ ve	3	353	33.9	0.0000		X	225	16.0	0.0001		X	324	30.7	0.0000		X
Technology (V074)	- ve	2	301	20.8	0.0000		X	202	24.5	0.0000		X					
New Systems/Ways (V056)	+ ve	2	361	12.5	0.0005		X	##	##	##	##		331	18.8	0.0000		X
In a small organisations management's understanding is top priority for success. (V065)	+ ve	1	348	10.8	0.0011		X	215	3.6	0.0582	B/L		#	#	#	#	
Tools, processes (V051)	+ ve	2	359	8.7	0.0033		X	T	T	T			327	4.4	0.0363	X	
Process Eng. (V052)	- ve	2	348	8.3	0.004		X	225	9.2	0.003		X	T	T	T		
Fragile/ Unbuffered (V055)	+ ve	1	305	7.7	0.006		X	T	T	T			T	T	T		
Small and regular (V071)	+ ve	2	310	4.0	0.0469	X		##	##	##	##		295	11.2	0.0009		X
The extent that a manager understands Lean is critical for success. (V064)	+ ve	2	344	3.9	0.0504	B/L							310	5.2	0.0233	X	
Repacking of JIT/Qual. Sys (V050)	- ve	1											305	8.8	0.0032		X
Comm. Process (V069)	+ ve	1											295	5.8	0.0169	X	

p<0.06 shown

ANOVA typical form F(df effect, df Error)=F   Oneway ANOVA here i.e. df effect = 1

= Difference observed over first likert increments but lost with aggregation of small and moderate extents

= Difference observed over extremeties small and very great extents

T = Trend forming but no significant differences observed

Highlighted values show interest especially where ranking differs

'df error' is indicative of total "sample" size for compared groups (n-2 in this case)

Figure 200 Significant differences found using One Way ANOVA by the key grouping variables - Low and High Familiarity; Low and High Experience; and Low and High Competitive Advantage. Chart ordered by Lean Familiarity.

Different Lean Definitions by Knowledge Level

From ANOVA, the different knowledge levels (familiarities) correlated with different understandings of lean. The significant differences found point to different definitions of lean. To formulate the definitions it was necessary to consider the actual Likert scale values (mean answers).

Scalar values and their changes were investigated. The key 'understanding' questions were on a five point scale from not at all to very great extent, numerically 0 to 4 with 2 being moderate. The most significant differences were found for 'Lean gives workers training and empowerment to solve problems'. As implementation experience and familiarity increased, question responses moved from 2 (moderate) to 3.5 (between great and very great extent), see example chart in Figure 201.[192] This was slightly smaller for lean as the business strategy and philosophy (2.4 - 3.5). Similar strengths (1 point increases) were observed for

[192] This chart and these figures were taken over the full range, from small extent familiarity to very great extent and was typical of implementation experience. Competitive advantage showed slightly wider ranges.

developed new systems and ways of doing things (2.3 - 2.9), waste elimination (2.4 - 3.4) and respect for people (1.5 - 3.1). All of these are essential to lean as opposed to just a part to a small or moderate extent. The view of lean as tools and processes for productivity improvement showed small 0.4 point effect, 2.2 - 2.6. Included in the understanding questions was "lean implementation process needs regularity and focus for sustained success". This had reasonable effect, 1.3 points, shifting from 2.3 - 3.6. Further implementation questions used an agreement approach; strongly disagree to strongly agree scale from 1 to 5 with 3 being neutral. Small effects were observed for having small and regular events (4.2 - 4.6). This was across all variables. Managements understanding being a top priority for success (V065) showed differences that were smaller again (4.5 - 4.7).

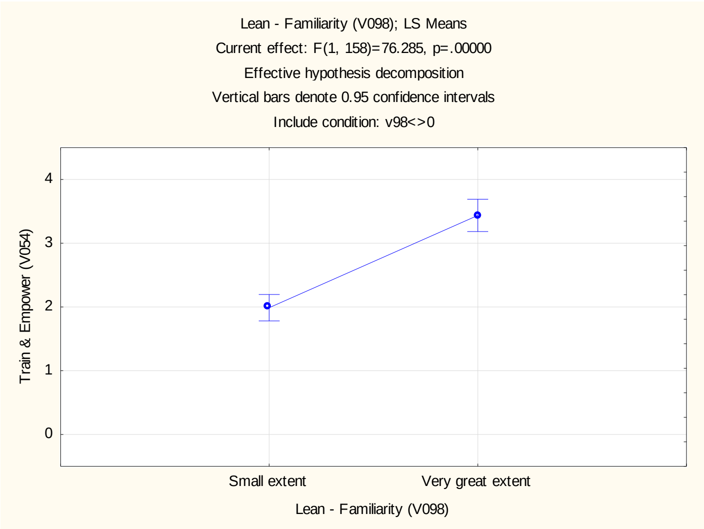


Figure 201 Lean is Training and Empowerment by Familiarity ANOVA (0 = Not at all, 4 = Very great extent)

The understandings at 'higher' familiarity had more absolute results than lower familiarity e.g. 3.5 (out of 4) compared with 2. This made its 'definition' easier to extract. The lower level of understanding (associated with lower knowledge[193]) was more difficult to describe. Results did not show polar differences. Responses did not shift from 0.5 to 3.5 (~ not at all to great extent) as knowledge level increased.[194] Typical effects were from a mean of 2 to a mean of 3 or 3.5; as in the sample chart Figure 201. Because low familiarity levels gave moderate mean values (~ 2), the common understanding, or definition was difficult to define.

Various reasons for moderate responses were investigated. The questions could have missed key important factors. This is deemed unlikely as text responses showed no significant additions. There was possibility that the question was misunderstood. Participants' could have answered their knowledge level of the method rather than what they thought lean was. This also is unlikely. The question was "Do the following statements match your understanding of lean?" This is reasonably clear. The scale was an extents scale and aimed to point towards their understanding rather than just their agreement or guess at what lean was. Feedback from

[193] Lower familiarity and implementation experience as well as competitive advantage.

[194] That is as familiarity and implementation experience increased from low to high levels.

pilot survey showed no confusion. And negative relationships (with increased familiarity) were observed indicating it was not a base level of how much knowledge but of opinion. Box plots comparing high and low familiarity (small and very great extent) showed the moderate results come from wide range of responses, Figure 202. Frequency scatter plots brought further clarity (Figure 203, Figure 204, Figure 205, and Figure 206).

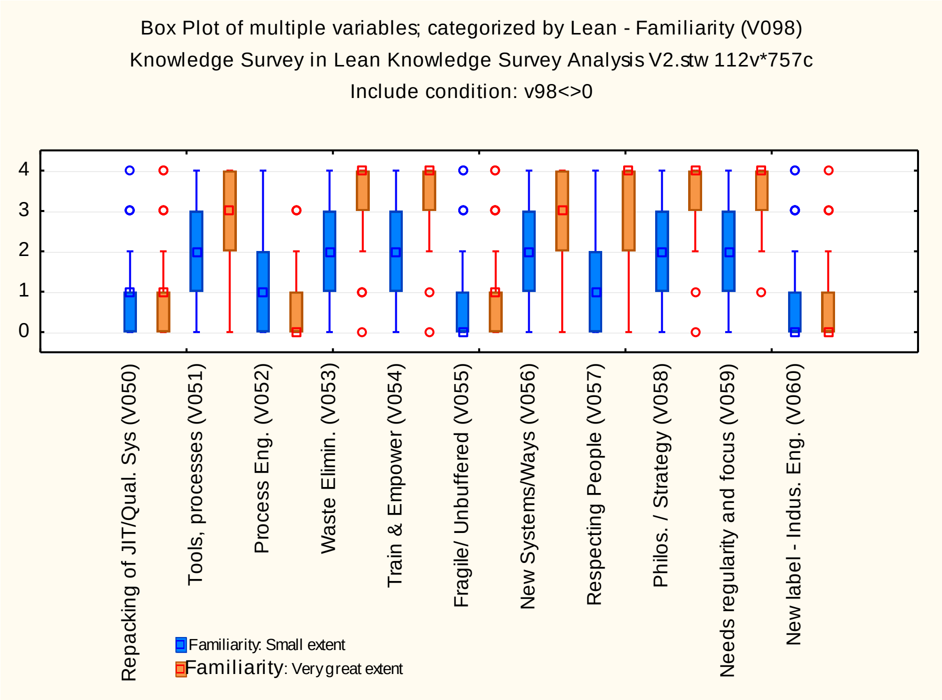


Figure 202 Understanding of lean – split by Familiarity Box Plot (Left hand side = Small extent, Right hand side = Very great extent; 0 to 4 scale is Not at all to Very great extent)

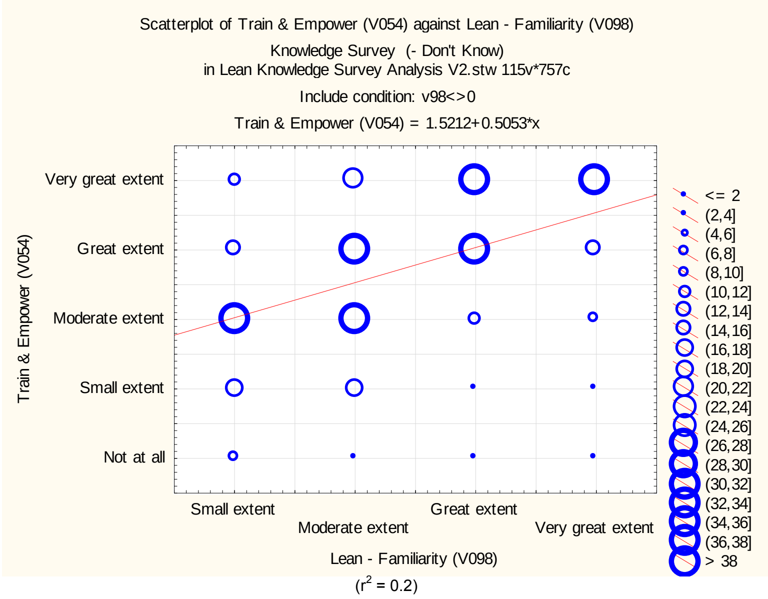


Figure 203 Lean is Training and Empowerment (V054) by Familiarity Scatter Plot.

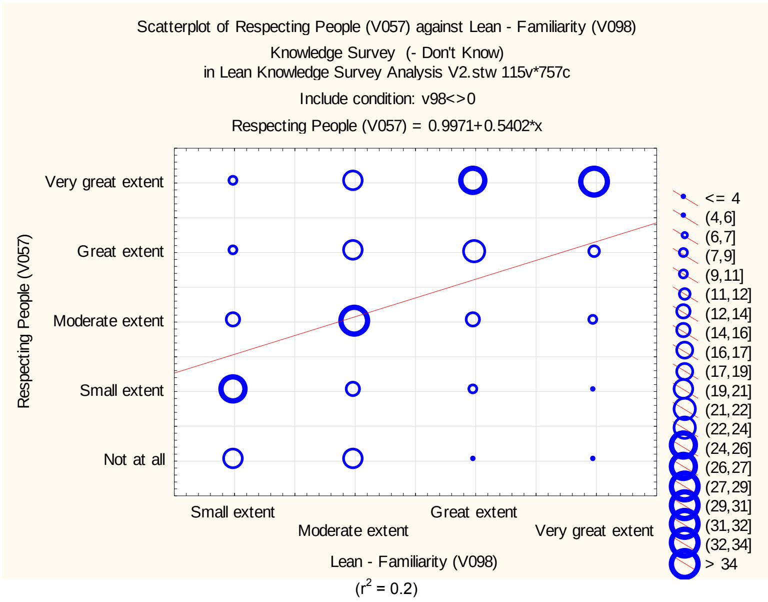


Figure 204 Lean is Respecting People (V057) by Familiarity Scatter Plot

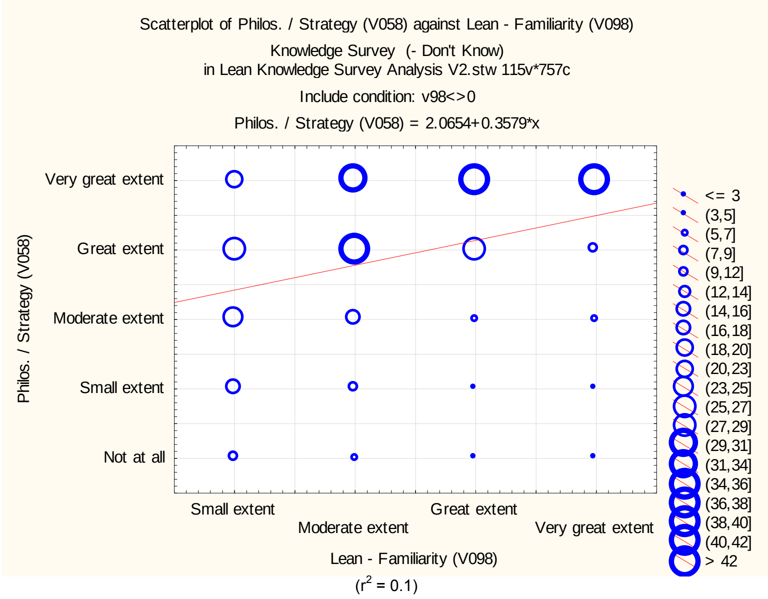
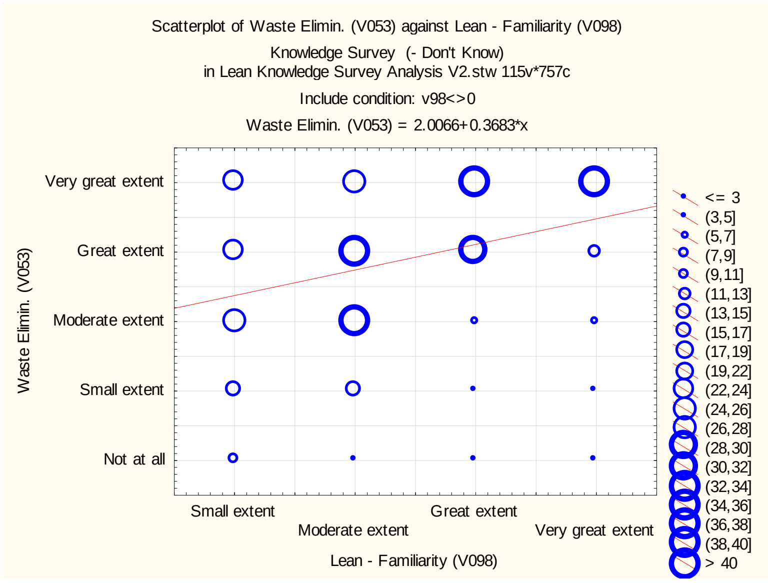


Figure 205 Lean is Philosophy and Strategy (V058) by Familiarity Scatter Plot



(r^2 = 0.1)

Figure 206 Lean is Waste Elimination (V053) by Familiarity Scatter Plot

Investigating the box and scatter plots at small extents familiarity gave the following results:

- Lean is Training and Empowerment (V054) showed wide range but stronger representation of mean at moderate level, Figure 203.
- Lean is Respecting People (V057) showed a range of responses but emphasis at small extents of respect for people, Figure 204.
- Other variables showed less divergence to a mean and general disagreement among the group, as typical of Figure 205 and Figure 206.

Although advanced knowledge (familiarity and experience) explained much of the shared variance, there was underlying constructs that needed uncovering.

Additional Results

Competitive advantage did identify two variables that familiarity and experience did not. They were weaker relationships. These was a negative correlation with lean as simple repacking of JIT and quality systems, nothing new (V050, $F[1,305]=8.8$, $p=0.003$); and the importance of developing an effective communication process for lean (V069, $F[1,295]=5.8$, $p=0.01$).The first of these weaker relationships is more historical or philosophical, it featured in factor analysis construct 2. It however was weak in the familiarity plane, and not part of the principal factor. It was eliminated through factor analysis. The need of a strong communication process was related to implementation. All levels of familiarity and experience rated the communication process as important scoring means of 4.5 (agree/strongly agree). There was strong agreement across all levels, no effect was found.

Participants generally agreed regarding implementation. Along with communication needs, participants agreed that implementation should focus on small and regular events, and learning the best methods. Similarly, that implementation shouldn't focus on key staff only and was neutral regarding use of management pressure.

The secondary construct from factor analysis (tools and process view) did show difference regarding implementation i.e. a top down approach involving management pressure, key staff only and technology focus. This did not significantly affect the differences found in the lean familiarity plane. Indications were the secondary construct existed in a basic form at low knowledge levels i.e. lean is tools and processes. Although persisting among some, it was weakened as familiarity increased. The third factor (correlating with factor, the holistic view of lean) gave a developmental view of implementation. The factors that correlated were: communication process, developing staff identity, learning the best methods, small and regular events, and simple techniques.

For summary of all effects and their comparisons see ANOVA Figure 200 and compare with Factor Analysis Figure 57.

Managements' Understanding

The importance of managements' understanding was investigated. It was reported to be greatly important for management to go be beyond basic commitment to lean to an in-depth understanding. The question "The extent that a manager understands lean and lean implementation is critical for the success of lean" shows general agreement of importance (4.5/5) across all participants with no significant differences by familiarity or implementation experience. Arithmetic means plot showed a trend (difference) for lean implementation, but the adjusted LS means (as used in the ANOVA plot) does not (see additional charts see Figure 34 through Figure 40.). By competitive advantage did show a small significant effect $F(1,310)=5.2$, $p=0.02$). See Figure 200. The questions "In a small organisations management's understanding is top priority for success” showed correlations by all three grouping variables (Figure 200). This question was much more specific about the commitment a manager should make, i.e. “understanding of lean should be the first and top priority”. This emphasis supported more differences that are significant.

The defining of management commitment is supported. It is believed that true commitment is top management’s full involvement in lean, understanding its principles, methods, and implementations effect with situational variables. Stronger trends seen here by perceived competitive advantage further indicate importance of this emphasis. This point is made more poignant when considering many managers inflated view of their knowledge of lean i.e. their self-deception.

Lean and Lean Implementation

Lean implementation involving new technology showed significant mid-size effects ($F\sim20$, $p<0.0001$) for familiarity and experience but not competitive advantage. This variable showed no direct relationship between attitude towards technology and competitive advantage. For all grouping variables (familiarity, experience and advantage) means plots showed narrow confidence bands around a “neutral” response but large ranges were observed (box and whisker plots).

Clearly best practice is not defined amongst lean practitioners. Although high familiarity and experiences shows reduced inclination towards technology, no correlation was found to a competitive advantage. It is reasonable to assume that, although technology is not core to lean, technology use may provide advantage or disadvantage to success where specific situational variables appear. Further work by case studies is needed to define technologies role in lean success and failure as well as defining what specific technologies are considered helpful or harmful.

Small Differences Produce Big Effects

Some variables only showed small effects. In actual implementation, these small effects could significantly alter success. The mall differences in practitioner’s attitude could alter their approach. Take the example of management commitment. If a manager considers their commitment extremely important then commitment will continue to be strong as other business objectives rise. However, someone who considers their commitment of lesser importance (although still very important) will more likely drop their participation at the first sign of competing objectives.[195]

13.1.2 Descriptive Analysis

Familiarity with Methodologies

Figure 207 shows a plot of methodology familiarity for lean across all responses (including biased groups) showing 42% “Not at all” indicating no knowledge of lean.[196] Other categories of familiarity were small

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[195] If it was possible to remove the positivity bias of self-report it would further widen the gap between what was reported and reality.

[196] For familiarity questions “don’t know” responses were grouped with / recoded as “Not at all”.

extent 18%, moderate extent 18%, great extent 12%, and very great extent 22%. Figure 208 shows the same plot with biasing groups removed. This shows 55% with no knowledge of lean at all, with familiarity to a small extent 17%, moderate extent 12%, great extent 9%, and very great extent 6%. These profiles were typical for each methodology with only slight variations. The exception was Cost Accounting seen in Figure 209 with much higher levels of familiarity (only 25% with no familiarity) and to some degree Quality Systems (35% no familiarity), Figure 210.

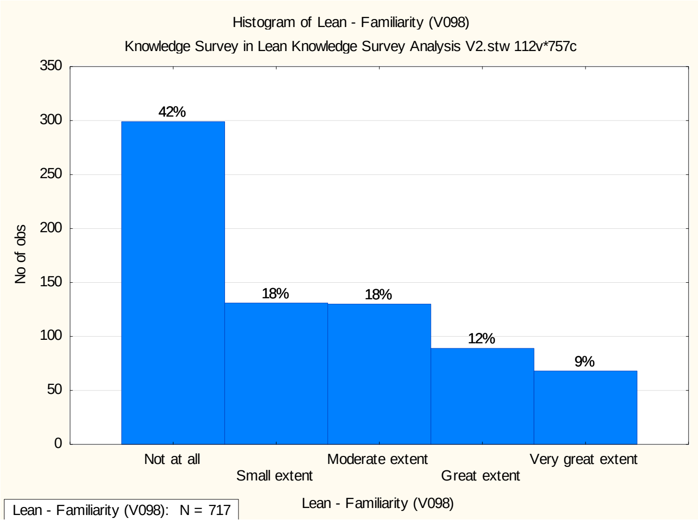

Figure 207 Familiarity with lean Histogram (all responses).

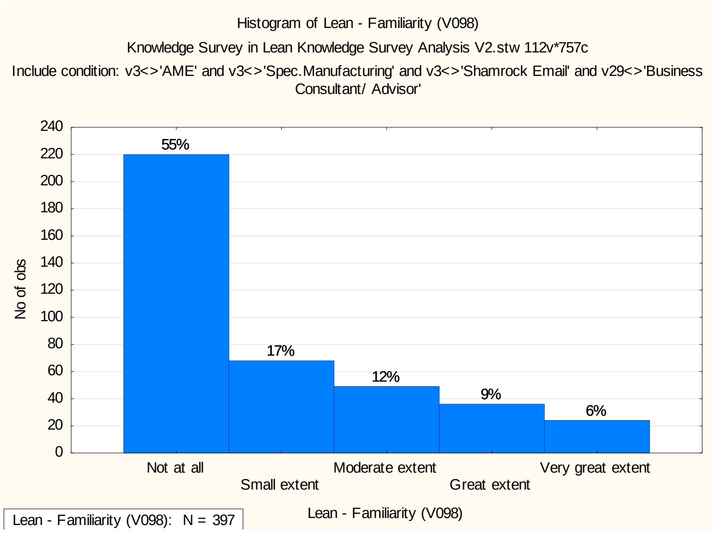

Figure 208 Familiarity with lean Histogram (bias groups removed).

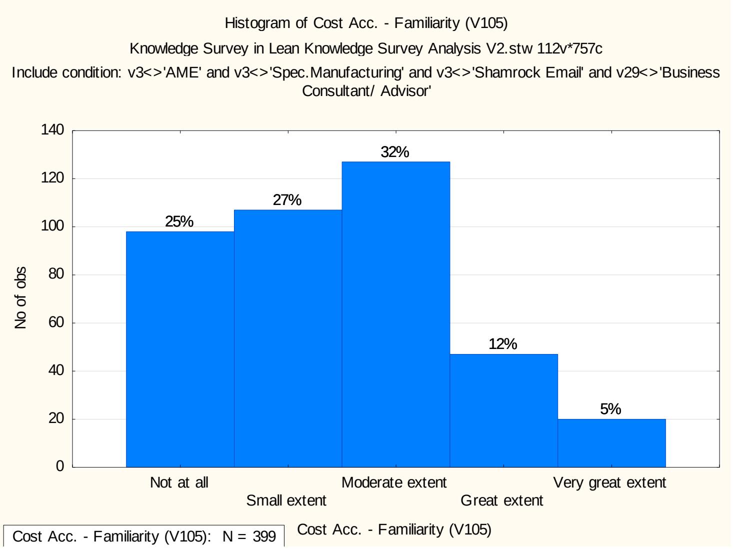

Figure 209 Familiarity with Cost Accounting (bias groups removed).

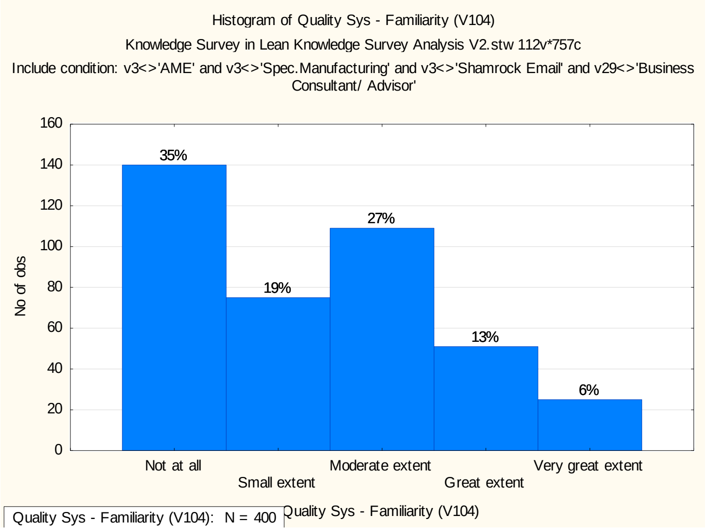

Figure 210 Familiarity with Quality systems (bias groups removed).

Implemented Methodologies

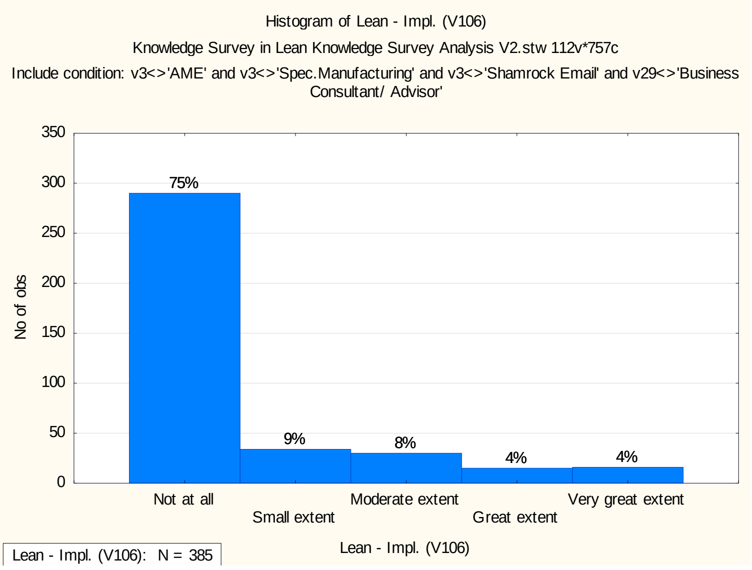

Figure 211 Implemented lean – Histogram (bias groups removed)

The extent to which participants had implemented the methodologies showed similar results. A typical profile.is seen in Figure 211 Implemented lean – Histogram (bias groups removed) and Figure 212 showing slightly higher application in the area of quality systems.

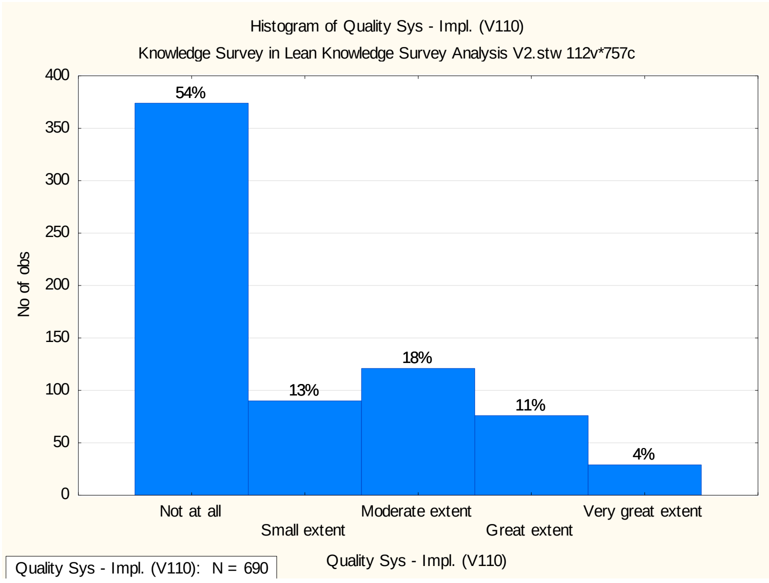

Figure 212 Implemented Quality Systems – Histogram (bias groups removed)

Further analysis looking at cross sections could uncover which subsections knew and implemented what methods and with what degree of success. However, that is for future work. This is a broad stroke analysis of how many participants were familiar with utilised these methods and specifically lean. It was obvious that lean and similar systems thinking methods are not well taught or utilised.

Lack of Understanding and Application of Methods

The above clearly identifies a lack of understanding and application of improvement methods. With each method, over half of the participants had not even heard of the methods and likewise less applied. Many would argue the methods are irrelevant to their work this was a common statement seen in textural responses.

Manufacturing Sector Still Limited lean Knowledge Saturation

Looking specifically at the manufacturing sector there is still not a strong presence of lean knowledge. 17 % of participants in the manufacturing have no familiarity with lean and 19% were familiar to a small extent. This means 36% had no or only a small knowledge of lean (Figure 213). Excluding manufacture sector shows 56% with no knowledge and no one with a very great extent of knowledge (Figure 214).

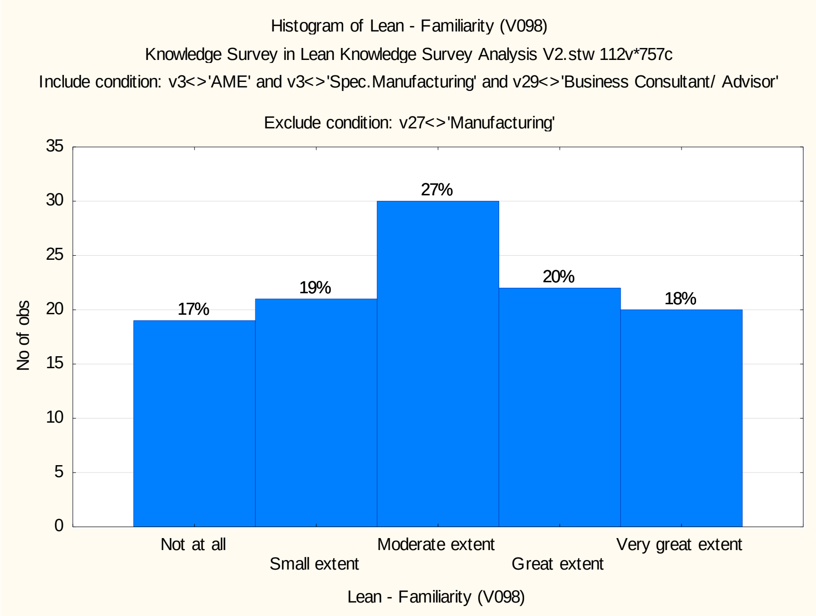

Figure 213 Familiarity with lean – Manufacturing Sector – biased groups removed.

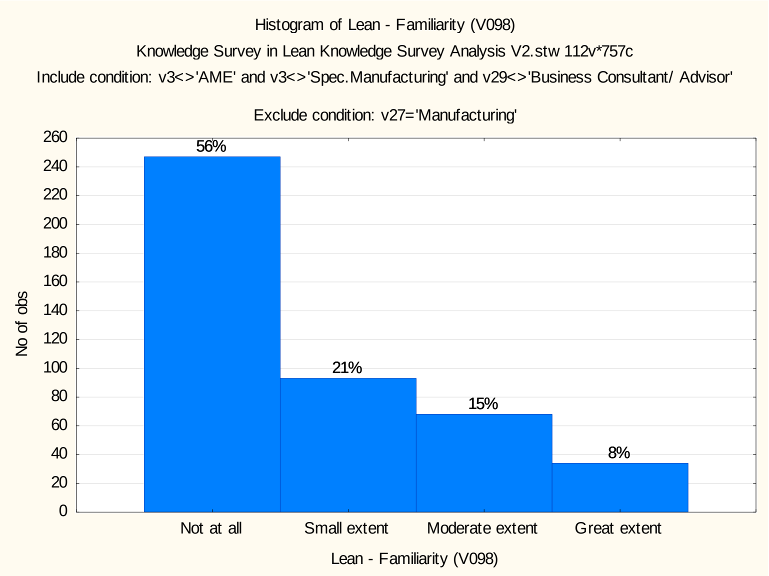

Figure 214 Familiarity with lean – Non Manufacturing Sector – biased groups removed.

Box means plots of familiarity by role (Figure 215) show a larger range for familiarity in middle management and technical roles than senior management although the mean for senior management is higher. It is interesting that owner-operators typically had less familiarity with lean. This is in line with the interest in supporting smaller businesses that face further challenges finding themselves with less available resources and expertise. They may feel themselves self-sufficient (as indicated by text responses) but in doing so miss their true business performance potentials. The lack in performance of small businesses no doubt cripples the performance of New Zealand as a significantly SME based economy.

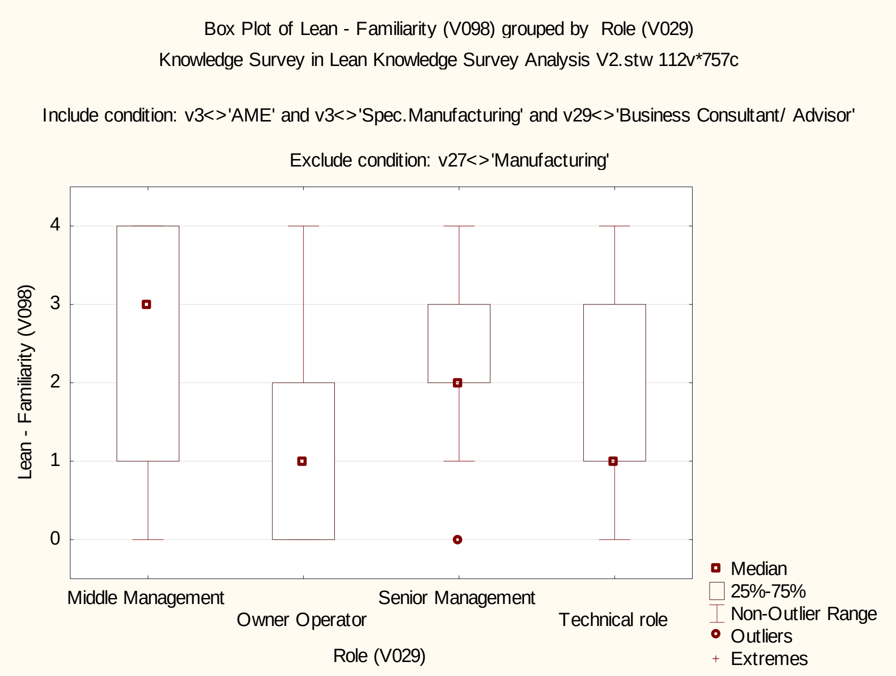

Figure 215 Familiarity with lean Box Plots by Role – Manufacturing Sector – specialised biased groups removed.

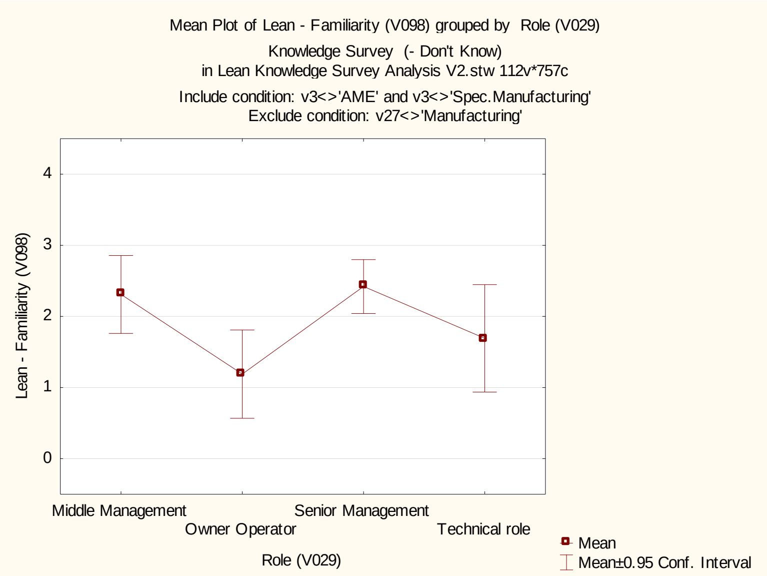

Figure 216 Familiarity with lean Means Plots by Role – Manufacturing Sector – specialised biased groups removed.

Comparing familiarity histograms by role shows different distributions. The distribution for senior management shows relatively normal form, Figure 217. Owner operator familiarity shows skew towards no familiarity (43%, Figure 218), this is concerning yet a reasonably expected distribution. Middle Management (Figure 219) shows a non-normal distribution seemingly bi-modal even though a similar number of responses to Senior Management (n = 29 cf. n = 38). Similar non-normal distribution appears for technical role (Figure 220) although responses numbers are low. It is believed the bimodal distribution occurs in lower levels in an organisation. Thus, it is typically dependent on whether or not the leadership have exposed their staff to lean, is typically driven from the top down. This supports the framework for knowledge entrance into the business through management.

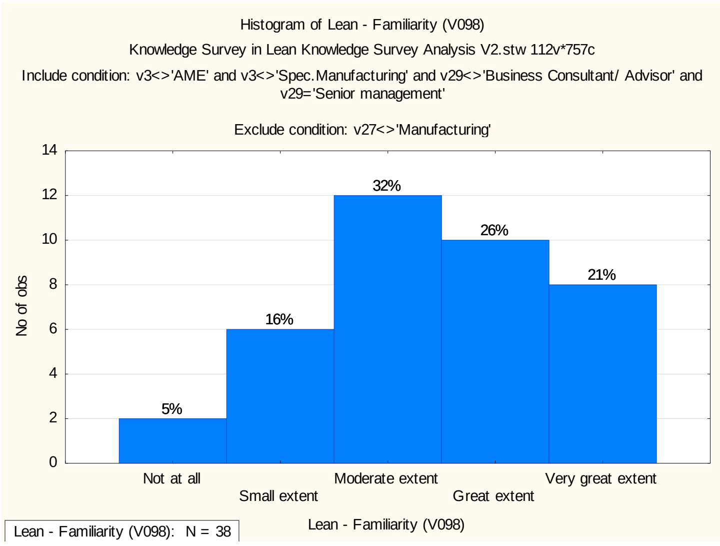

Figure 217 Familiarity with lean - senior management –Manufacturing Sector – biased groups removed.

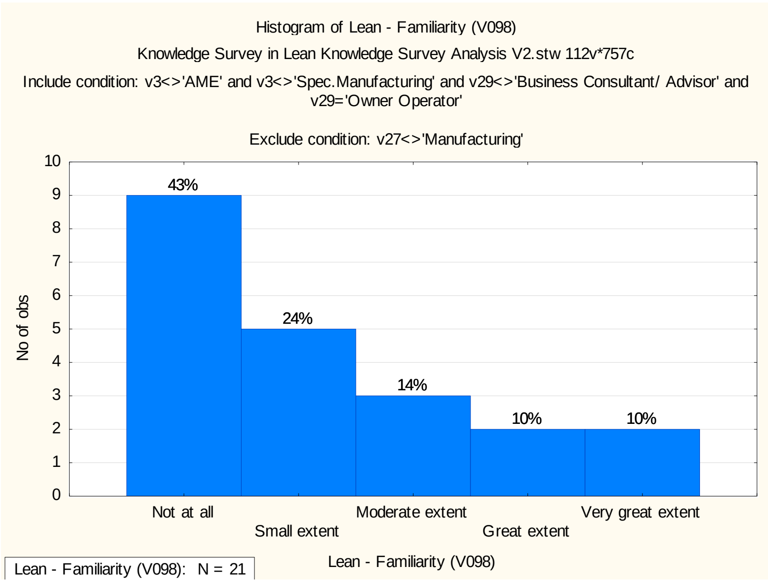

Figure 218 Familiarity with lean - Owner Operator –Manufacturing Sector – biased groups removed.

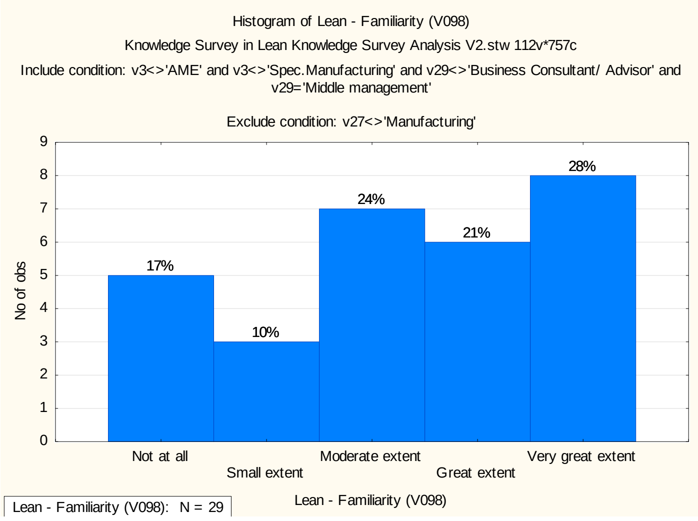

Figure 219 Familiarity with lean - Middle management –Manufacturing Sector – biased groups removed.

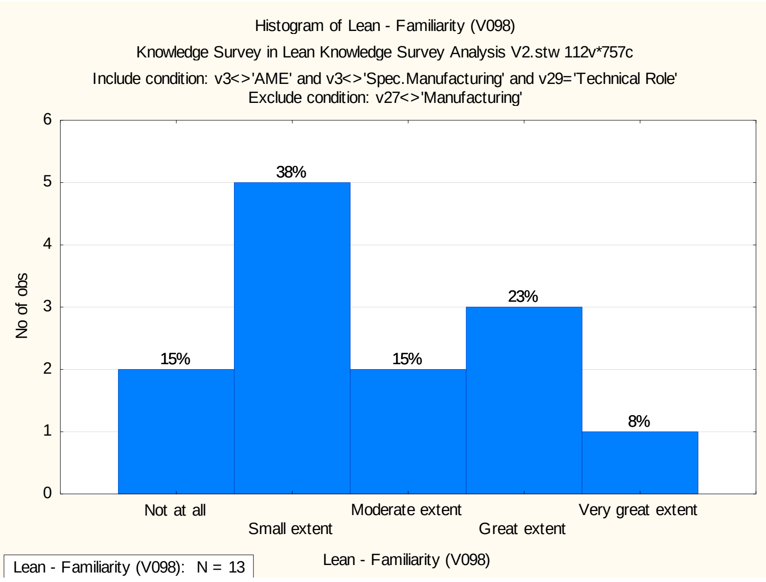

Figure 220 Familiarity with lean – Technical role –Manufacturing Sector – biased groups removed.

Familiarity by Region and Education level

This is an expansion on the same work found in the body of the thesis.

There were no significant differences found for lean familiarity between regions (countries) and education groups[197] except when specifically looking at the manufacturing industry. Figure 221 shows a means plot for

[197] Once biased groups were removed.

country grouping. The 95% confidence error bands[198] clearly overlap for each category except "other" which has a higher mean but carries large error bands. It is clear particularly where error bands are smaller that New Zealand does not lag significantly behind the likes of United Kingdom or the USA in their approach to education in lean thinking rather it performs just as poorly as the other countries. Figure 222 and Figure 223 compare for Familiarity by highest education level. For manufacturing there is a trend as education increases but this would be expected (Figure 223).

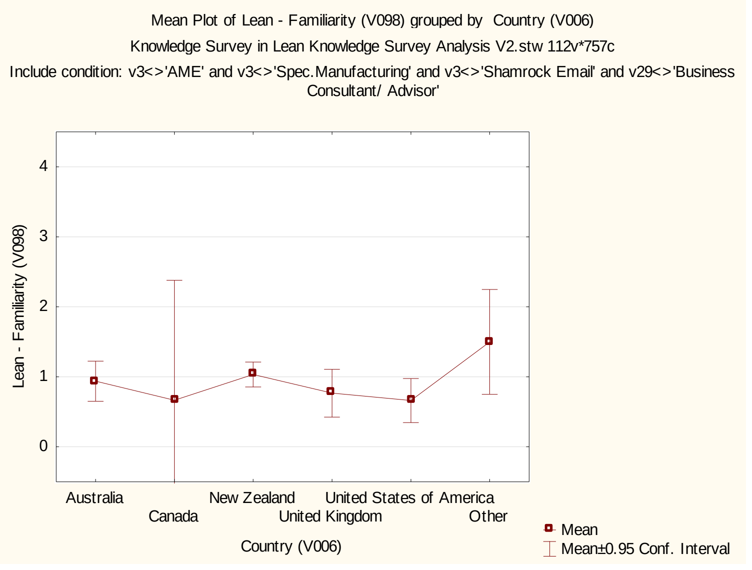

Figure 221 Familiarity with lean – Means Plot by country - biased groups removed. No significance difference by country. (0 = not at all, 4=very great extent)

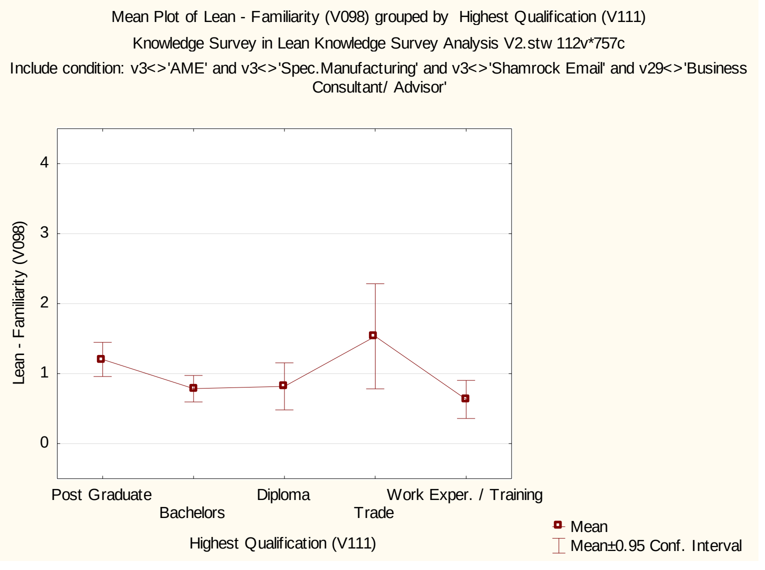

Figure 222 Lean Familiarity by Highest Qualification means plot showing no significant different by education level. Biasing manufacturing groups were removed.

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[198] The error band indicates the certainty of the mean displayed. In simplistic terms the more responses in a certain category the more certainty there is that the mean of the sample (as displayed on the graph) represents the actual mean of the entire population. The error bands become smaller as the certainty or confidence in the mean increases.

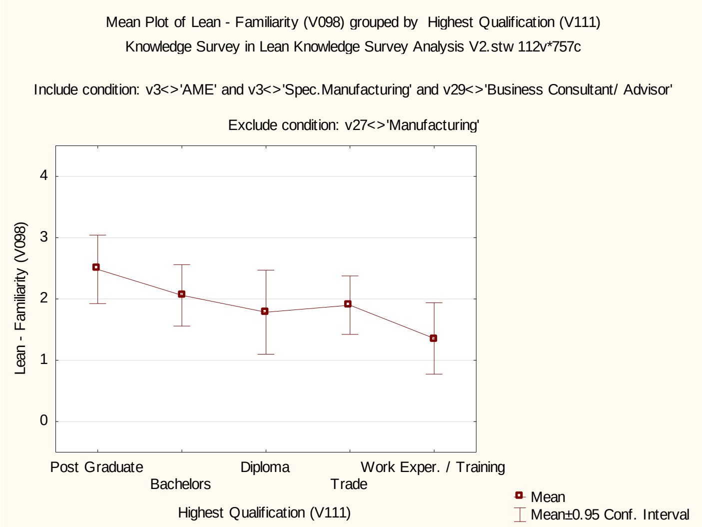

Figure 223 Lean Familiarity by Highest Qualification means plot showing no significant different by education level. Filtered for manufacturing industry (biasing sample groups removed).

Given a comparison across similar industrial sectors, it is believed that lean knowledge saturation would be less in New Zealand compared with other countries. Further survey distribution would be required for significant results across a number of countries.

New Zealand Manufacturing: Time to Catch Up!

(This is an expansion on the same work found in the body of the thesis.)

The lethargy in New Zealand to contemporary methods was observed. The data showed significant differences between the countries of United States and New Zealand when filtered for manufacturing. This indicates New Zealand has indeed been slow on the uptake of lean manufacturing. Further responses from manufacturing participants from the United States (Figure 224) would be desirable to further increase confidence, reduce error bands, but results are still very strongly significant with $F(1,87) = 19.2$, $p = 0.00003$ (Figure 225). This indicates the lethargy in New Zealand managers as expressed in Hypothesis 4:

> ***Hypothesis 4: New Zealand's senior managers (represented largely by those in SMEs) have been slow to pick up lean management.***

Demographics showed that management seniority and experience were comparable although New Zealand included some businesses of lower staff numbers and participants were not asked about product mix. Although arguments could be made regarding product mix and organisation size the implications are that New Zealand is resting on its laurels regarding productivity thinking and needs to catch up with overseas counterparts in order to perform in the international market. Textural responses indicated that lean is shifting from being a competitive advantage to becoming an essential core competency.

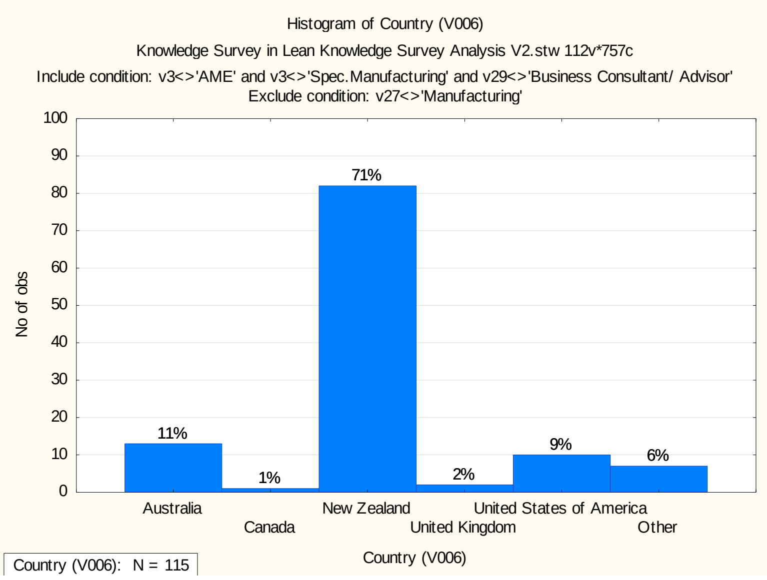

Figure 224 Histogram for Manufacturing Participants by Country (specialist bias removed).

Figure 225 Familiarity with lean – Means Plot for Manufacturing Sector Comparing New Zealand and the United States - biased groups removed. Significant difference found: p=0.00003, F(1,87)=19.2. (0 = not at all, 4=very great extent)

Self-Deception: Self-Reported Great Familiarity but Tested Knowledge Low

(This is an expansion on the same work found in the body of the thesis.)

It was believed that many participants are deceived about their knowledge of lean. This matter was highlighted for investigation when reviewing pilot survey results. A participant would have been estimated as having moderate knowledge of lean self-reported "great extent". This showed a confidence in their knowledge of lean beyond what would have been considered reasonable. There was an indication self-deception. Actual knowledge level could be assessed by alternative question responses. Self-deception was evident in analysis where participants who reported to having familiarity with lean to a great extent actually had no knowledge of basic lean principles or methods.

The plots below show histograms for the base question "*To what extent would the following be relevant to your organisation?"* Figure 226 through Figure 228 show responses for participants who answered "Great extent" familiarity with lean. These plots are for very basic methods of lean i.e. the 5S system, kanban, and standard work. Someone with a moderate familiarity would be expected to identify these.

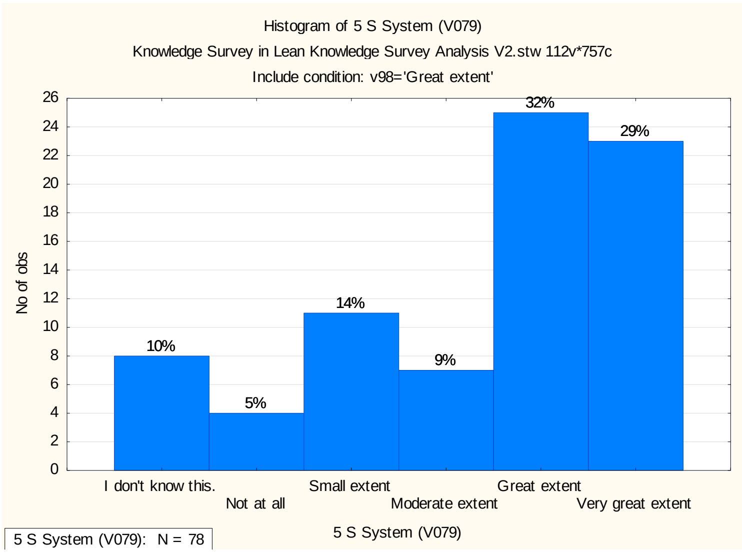

Figure 226 "5S system" relevance to organisation for lean familiarity = Great extent.

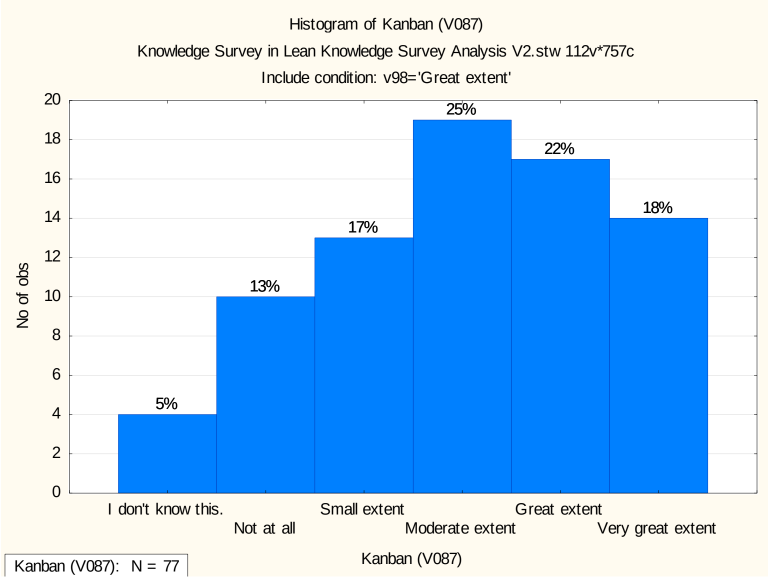

Figure 227 "Kanban" relevance to organisation for lean familiarity = Great extent.

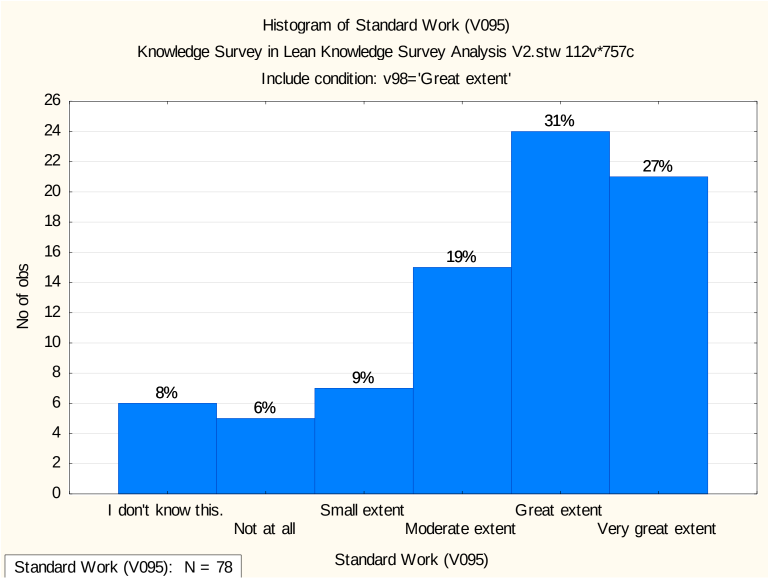

Figure 228 "Standard work" relevance to organisation for lean familiarity = Great extent.

5S, for example, is a fundamental lean method and typically the first for implementation. 5S would also be considered valid to all industries and roles (e.g. factory floor or personal office, computer files or operating theatre). 5S is something that is implemented and must be sustained. A significant portion of participants who answered they a high (great) familiarity with lean answered either they did not know the concept (10%), it was not at all relevant (5%), or only relevant to a small extent (14%). Adding 9% who answered moderate extent gives 38%. 38% of participants answered this key method for lean practice was not relevant, only relevant to a small extent, or only moderately relevant. This being typical across the basic methods of lean is seen as strong evidence to self-deception amongst many participants who considered they knew lean to a great extent. Arguably, 38% of participants showed self-deception by this question.

This self-deception regarding their level of understanding of lean is appearing as a major influence on lean success and failure. This was highlighted by practitioner interviews and case studies and confirmed by this result. This self-deception would spread beyond methods to all core concepts and understanding of lean. If an organisations leadership believes they understands lean to a great extent where in actual fact their knowledge only scrapes the surface then decision making is prone to error. One result would be not embarking on a lean implementation at all (failure). Another embarking on a substandard implementation that is misguided and prone to failure. Although a leader may believe that a high level of understanding is crucial in implementing such change (as seen by responses, p. 386) they may be self-deceived into thinking they have an adequate level of knowledge. Such poor implementations become another event of poor change management history effecting impressions of lean "confirming" it as another "fad". It is believed believe the fad is to embark on lean self-deceived that you actually know what lean is!

This discussion gives further resolution to the problem of lethargy in Hypothesis 4:

> ***Hypothesis 4: New Zealand's senior managers (represented largely by those in SMEs) have been slow to pick up lean management.***

Reasons for self-deception (resulting in lethargy) were not asked in this survey. It is believed two major factors influence this. One is that many older leaders with many years of experience have observed lean and similar methodologies over a long period of time. On one hand they neglect that the understanding of lean has developed and it is understood much more clearly than when it had barely emerged from JIT and TQM at the start of the 1990's. On the other, the mere prolonged exposure to lean, i.e. being partially applied in industry, gives them a false sense of strong familiarity and understanding. As suggested by iceberg models there is often more than is seen on the surface or briefly discussed. This is especially true when the understanding of a topic is developed in discussions with similarly minded practitioners whose own understanding may be limited. Based on the contextualisation study this was believed to be the case in New Zealand industry. The second point is the introduction and marrying of lean with six-sigma that may be beneficial to process improvement but has severely watered down the development of true lean thinking and as this survey's textural responses indicates can leave a poor taste and perspective of lean behind. Accompanying lean six sigma certification also brings false sense of knowledge as well with other short courses that scrape the understanding of lean and leave participants with a false sense of knowledge and a strong tools and consultant focus. Unfortunately (good intentions aside) it is believed this is still the result for many participants on the New Zealand Trade and Enterprise introduction to lean courses.

Qualification: Situational Variables Not Explored

The work crosses many sectors with different product types and other situational variables. One could argue that some of the tools and methods are more relevant to certain industries than others due to these situational variables. Although it is agreed that certain methods, e.g. JIT manufacture and Six-sigma, are not ideal for all circumstances you would still expect someone with a great knowledge of lean to be familiar with them.

Second, although someone may not find JIT or Six-sigma applicable to their business it is hard to believe that the likes of 5S or 5whys are not relevant to most if not all industry.

Lean Methods

The survey included the methods of lean. The question asked applicability of those methods to the participant. Exploratory Factor Analysis uncovered no specific insights except to split the Lean understanding group (Factor 1) into one correlated with applicability of the methods and those not. This could have been confounded by those who did not know the lean methods so answered ‘not at all’.

Textual Insights

Erroneous Views

The miscellaneous textural responses echoed and strengthened other findings. Text responses gave insights to where failure initiates. One repeated erroneous view was that lean is a tool and management should focus on business strategy (4, 6%). This view ignores the strategic level of lean as a holistic system providing customer value. It indicates lean is tools to be applied in piecemeal fashion by the likes of consultants and production specialists without management bearing responsibility. Such an application is not associated with sustained improvement or the true benefits of a highly aligned lean business and excellent learning organisation. A similarly dangerous view was lean “doesn’t have to be boxed that way and some do it intuitively” (4, 6%). Other comments include that “we do many things lean” and just don’t call it lean. It is agreed that lean can be presented under another name or in an integrated system. The danger, as observed in the case studies, is the neglect of the holistic approach needed for success. Statements like this indicate a piecemeal application and lack of the necessary commitment. Conversely, comments raised the need for a holistic approach (8%), and the correct application (6%) of lean. Specifically the current state of industry was described as ‘LAME’ - Lean Applied Misappropriately Everywhere. Piecemeal lean usage is common but not associated with true success as is the holistic approach, embracing and understanding the core concepts.

Other interesting comments included that small businesses are already lean implying they don’t need to apply lean (1 comment, 1.4%), they have not needed lean before so why now (showing good performance is a reason for some not to try to do better), and that lean is considered a fad (1%).

Lean is a core Competency

Textural responses were recorded regarding lean as a competitive advantage. The highest number of responses, 12% of participants, indicated lean was now a core competency in many industries. These considered lean not a competitive advantage in itself but a necessity. Participants noted that how well you “do” lean was now the competitive advantage.

Textural tally charts can be found under Textural Responses, p. 416.

13.1.3 Understanding of Lean—ANOVA Analysis Charts

The principal analysis was of the different understandings of lean. The analysis used three variables for grouping participants for ANOVA comparisons.

Grouping Variables: Analysis Input Variables

The key grouping variables are the main independent or input variables used for analysis. These key grouping variables were participants' scalar responses. These key variables were (A) their familiarity with lean, (B) the extent to which they had implemented lean and (C) their view on how much of a competitive advantage lean is. There were three main sections of questions that were compared. These were based around the understanding of lean, what was important in implementation and the importance of leadership or management's knowledge of lean. The main variable for the analysis was lean familiarity as this study purpose is to unveil the influence of lean knowledge. The key questions for analysis were the "understanding" questions:

Variable Name	Do the following statements match your understanding of lean?
Repacking of JIT/Qual. Sys (V050)	[Lean is simple repacking of JIT and quality systems, nothing new.]
Tools, processes (V051)	[Lean implementation is of tools and processes for improving productivity.]
Process Eng. (V052)	[Lean is tools or methods primarily for process or industrial engineers.]
Waste Elimination (V053)	[Lean means eliminating waste.]
Train & Empower (V054)	[Lean gives workers training and empowerment to solve problems.]
Fragile/Unbuffered (V055)	[Lean means fragile (i.e. without buffers).]
New Systems/Ways (V056)	[Lean is implementation of new systems and ways of doing things to improve productivity.]
Respecting People (V057)	[Lean means respecting people.]
Philos./Strategy (V058)	[The implementation of a company wide philosophy and strategy.]
Needs regularity and focus (V059)	[Lean implementation process needs regularity and focus for sustained success.]
New label - Indus. Eng. (V060)	[Lean is a new label for industrial engineering and the work of industrial engineers.]

Participant answered on a 5 point scale: not at all, small extent, moderate extent, great extent, and very great extent, or indicated they did not know.

Comparing High and Low levels by ANOVA

The analysis mainly reported significance between High and Low levels of lean knowledge e.g. small extent with very great extent groups. The difference between low and high groups, e.g. low and high knowledge levels, was desired. It was stronger to group data into 'low and high' categories, i.e. grouping small extent with moderate extent to form 'low' and great extent with very great extent to from 'high'.

Summary Table: Key Questions Analysed by Key Grouping Variables

The analysis of survey questions on lean understanding and implementation gave statistically significant insights. The detailed technical analysis included viewing trends and any non-linear transitions by means plots. Two tables were used to summarise:

> Figure 230 Key Question Analysis by Grouping Variables. Summary of the significant differences for One Way ANOVA by the key grouping variables (lean familiarity, implementation experience, and competitive advantage).
>
> Figure 231 Ranking of the significant differences found using One Way ANOVA the key grouping variables. Ordered by competitive advantage, then lean familiarity.

Explanation of Table Format

The rows of the tables give variables and individual variable statistics. Columns next to the variable names show whether significant differences (defined by $p<0.05$) were found for that variable and what direction was the relationship (positive or negative correlation). Figure 230 also showed how many of the three grouping variables (familiarity, implementation experience and competitive advantage) found a significant difference (relationship) for each variable. This table grouped by "low" and "high" where low combined responses "small" and "moderate" extent and high combined responses "great" and "very great" extent.

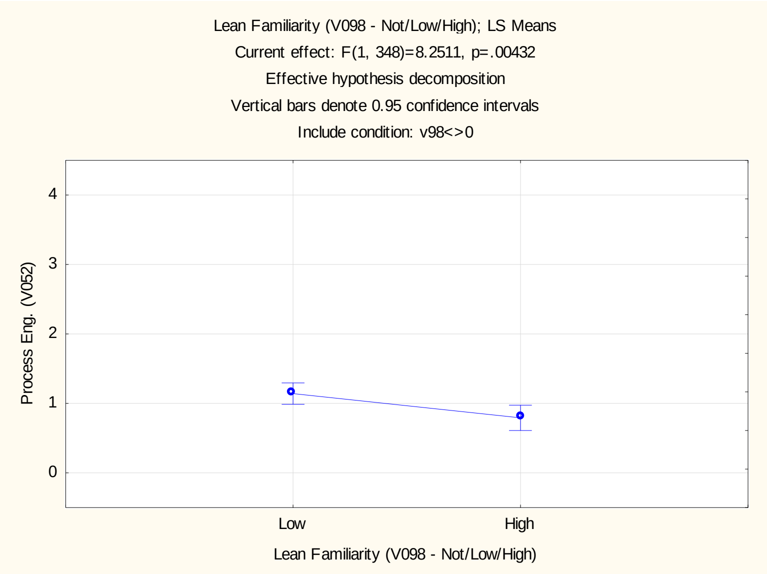

Figure 229 Example chart: Lean is Tools and Processes primarily for Process Engineers by Lean Familiarity Low/High ANOVA (0 = Not at all, 4 = Very great extent)

The main columns display one way ANOVA statistics for each grouping variable. The dF effect is not included as it is 1 for all. The dF error[199], F value and p value are all included. An example for the third variable (Process Eng. [V052]) according to the column Familiarity [V098] Low to High is given in means plot form as Figure 229.

[199] In rough terms the dF error indicates the sample size for that calculation (~ n-2, as this is one way ANOVA).

					Across Full Available Likert Range														
					Familiarity (V098) Low cf. High					**Implementation Experience** (V106) Low cf. High					**Competitive Advantage** (V062) Low cf. High				
	Variables																		
	Variables in question order	Found p<0.05 Yes/No,	Relati-onship +ve / -ve	Number That Found p<0.05	df Error	F	p	0.05=>P>0.01	0.01=>P	df Error	F	p	0.05=>P>0.01	0.01=>P	df Error	F	p	0.05=>P>0.01	0.01=>P
	Understanding Lean As																		
1	Repacking of JIT/Qual. Sys (V050)	Y	- ve	1	327	0.1	0.804			221	1.3	0.264			305	8.8	0.003		X
2	Tools, processes (V051)	Y	+ ve	2	359	8.7	0.003		X	233	0.7	0.402			327	4.4	0.036	X	
3	Process Eng. (V052)	Y	- ve	2	348	8.3	0.004		X	225	9.2	0.003		X	320	2.6	0.107		
4	Waste Elimin. (V053)	Y	+ ve	3	363	51.2	0.000		X	234	4.6	0.033	X		331	20.8	0.000		X
5	Train & Empower (V054)	Y	+ ve	3	356	80.7	0.000		X	232	24.7	0.000		X	324	54.7	0.000		X
6	Fragile/ Unbuffered (V055)	Y	+ ve	1	305	7.7	0.006		X	203	0.4	0.532			281	0.1	0.811		
7	New Systems/Ways (V056)	Y	+ ve	2	361	12.5	0.000		X	229	1.5	0.217			331	18.8	0.000		X
8	Respecting People (V057)	Y	+ ve	3	331	54.4	0.000		X	221	20.3	0.000		X	308	18.4	0.000		X
9	Philos. / Strategy (V058)	Y	+ ve	3	353	33.9	0.000		X	225	16.0	0.000		X	324	30.7	0.000		X
10	Needs regularity and focus (V059)	Y	+ ve	3	346	56.6	0.000		X	224	6.6	0.011	X		318	24.0	0.000		X
11	New label - Indus. Eng. (V060)	N		0	333	0.5	0.500			220	2.0	0.159			309	1.0	0.311		
														X					
	Implementation Importance													X					
12	Large impact (V067)	N		0	309	1.5	0.226			208	3.0	0.085			295	0.6	0.453		
13	Best Methods (V068)	N		0	307	0.1	0.787			205	0.4	0.535			292	2.4	0.124		
14	Comm. Process (V069)	Y	+ ve	1	311	2.2	0.142			207	0.1	0.702			295	5.8	0.017	X	
15	Staff Identity (V070)	N		0	305	0.1	0.805			206	0.5	0.481			290	3.6	0.059		
16	Small and regular (V071)	Y	+ ve	2	310	4.0	0.047	X		208	0.2	0.665			295	11.2	0.001		X
17	Key Staff Only (V072)	N		0	306	2.6	0.108			204	1.0	0.315			290	0.7	0.389		
18	Mgmt Force (V073)	N		0	278	0.1	0.748			193	0.9	0.341			266	0.6	0.441		
19	Technology (V074)	Y	- ve	2	301	20.8	0.000		X	202	24.5	0.000		X	287	0.0	0.964		
20	Simple Techniques (V075)	N		0	302	3.1	0.081			203	0.6	0.422			287	1.1	0.299		
	Management Understanding																		
21	The extent that a manager understands Lean is critical for success. (V064)	Y	+ ve	2	344	3.9	0.050			215	0.1	0.714			310	5.2	0.023	X	
22	In a small organisations management's understanding is top priority for success. (V065)	Y	+ ve	1	348	10.8	0.001		X	215	3.6	0.058			312	2.5	0.117		
	Summary Tabulation:	of 22			AVG.	Max.		Sum	Sum	AVG.	Max.		Sum	Sum	AVG.	Max.		Sum	Sum
		15	68%		327.4	80.67		1	11	215.1	24.74		2	7	304.4	54.69		3	8
		Found p<0.05	Found p<0.05						12					9					11
	Percentage of variables that this moderator found a signifcant difference for								55	%				41	%				50 %
	Percentage of variables that showed a difference that this moderator found								80	%				60	%				73 %

p<0.05 shown in red

p>0.05 included for reference

ANOVA typical form F(df effect, df Error)=F

Oneway ANOVA here i.e. df effect = 1

Highlighted values show interest

'df error' is indicative of total "sample" size for compared groups (n-2 in this case)

Figure 230 Key Question Analysis by Grouping Variables. Summary of the significant differences for One Way ANOVA by the key grouping variables (lean familiarity, implementation experience, and competitive advantage).

	Variables			Familiarity (V098) Low cf. High					Implementation Experience (V106) Low cf. High					Competitive Advantage (V062) Low cf. High				
				Across Full Available Likert Range														
	Variables Ordered by Comp. Adv	Relati-onship +ve / -ve	Number That Found p<0.05	df Error	F	p	0.05=>P>0.01	0.01=>P	df Error	F	p	0.05=>P>0.01	0.01=>P	df Error	F	p	0.05=>P>0.01	0.01=>P
5	Train & Empower (V054)	+ ve	3	356	80.7	0.000		X	232	24.7	0.000		X	324	54.7	0.000		X
9	Philos. / Strategy (V058)	+ ve	3	353	33.9	0.000		X	225	16.0	0.000		X	324	30.7	0.000		X
10	Needs regularity and focus (V059)	+ ve	3	346	56.6	0.000		X	224	6.6	0.011	X		318	24.0	0.000		X
4	Waste Elimin. (V053)	+ ve	3	363	51.2	0.000		X	234	4.6	0.033	X		331	20.8	0.000		X
7	New Systems/Ways (V056)	+ ve	2	361	12.5	0.000		X						331	18.8	0.000		X
8	Respecting People (V057)	+ ve	3	331	54.4	0.000		X	221	20.3	0.000		X	308	18.4	0.000		X
16	Small and regular (V071)	+ ve	2	310	4.0	0.047	X							295	11.2	0.001		X
1	Repacking of JIT/Qual. Sys (V050)	- ve	1											305	8.8	0.003		X
14	Comm. Process (V069)	+ ve	1											295	5.8	0.017	X	
21	The extent that a manager understands Lean is critical for success. (V064)	+ ve	2	344	3.9	0.050								310	5.2	0.023	X	
2	Tools, processes (V051)	+ ve	2	359	8.7	0.003		X						327	4.4	0.036	X	
15	Staff Identity (V070)		0											290	3.6	0.059		
19	Technology (V074)	- ve	2	301	20.8	0.000		X	202	24.5	0.000		X					
22	In a small organisations management's understanding is top priority for success. (V065)	+ ve	1	348	10.8	0.001		X	215	3.6	0.058							
3	Process Eng. (V052)	- ve	2	348	8.3	0.004		X	225	9.2	0.003		X					
6	Fragile/ Unbuffered (V055)	+ ve	1	305	7.7	0.006		X										
20	Simple Techniques (V075)		0															
17	Key Staff Only (V072)		0															
12	Large impact (V067)		0															
11	New label - Indus. Eng. (V060)		0															
18	Mgmt Force (V073)		0															
13	Best Methods (V068)		0															

p<0.05 shown in red — p>0.05 included for reference

ANOVA typical form F(df effect, df Error)=F — Oneway ANOVA here i.e. df effect = 1

Highlighted values show interest especially where ranking differs
'df error' is indicative of total "sample" size for compared groups (n-2 in this case)

Figure 231 Ranking of the significant differences found using One Way ANOVA the key grouping variables. Ordered by competitive advantage, then lean familiarity.

The findings of this analysis with the different understandings of lean are discussed as part of an integrated model. See Knowledge Framework from page 188 and specifically page 172. Particular insights of the tabulated summary and numbers of differences found are included here.

Figure 230 includes summary statistics for relationships found, which grouping variables showed the most effects and the most significant effects. The hypothesis includes that different understandings exist regarding lean. 68%, 15 out of 22 variables, showed significant differences ($p<0.05$) in understanding. Differences were observed in 91% of the variables when using finer intervals i.e. looking at small, moderate, great and very great extent rather than aggregated high and low.[200]

[200] This method could have lent to accusation of intentional biasing due to hand picking the finer increments. The safer results of high low are reported here.

The hypothesis mentions that a leaders understanding effects outcome success. This can be inferred by the perceived competitive advantage. The competitive advantage grouping showed 50% of the differences (implementation experience 41% and familiarity 55%). The competitive advantage effect grouping showed significant differences for 3 variables that the other key grouping variables did not and the familiarity grouping showed one. The large quantity of significant results show support for the hypothesis. In an analysis that added more resolution to the grouping variables (i.e. over full scale from small, to very great extents) the competitive advantage grouping showed more differences and indicated the strongest relationships.

Figure 231 is a simplified chart in which variables are ranked by effect size F. The simplification included removing unnecessary summaries and clearly insignificant statistics (F >5, p>0.07). The purpose was to organise by effect size (F value). Regards success the most influential and important variable was identified as competitive advantage i.e. equating to success. The table was sorted for F by Competitive Advantage and then familiarity.

Variable rank (ordering by F magnitude) was similar independent of the grouping variable chosen however; some differences were observed (Figure 231). Lean as Philosophy and Strategy ranked higher and Respecting People (V057) ranked lower by competitive advantage than would have by familiarity and implementation experience. Lean being tools for process engineers (V052) showed a significant negative relationship by familiarity and implementation experience but none by competitive advantage. Lean being implementation of technology (V074) also found very significant negative correlations by familiarity and implementation experience but none by competitive advantage.[201]

This summary table provided relevant insight:

A: 15 out of 22 variables showed significant differences regarding perceptions of lean. The majority of differences were common across all grouping variables.

B: Most of the differences were observed by lean familiarity (as well as the other variables).

C: Implementation experience showed the least differences but gave some additional insights. This shows that additional benefit and adjustment to concept came from further experience. It also clarifies that although some of the familiarity variable is explained by experience i.e. familiarity through implementation experience, not all of it is and there are differences.

D: Competitive advantage did not conform completely with the other variables but showed strong relationships, trends and some different emphasis.

[201] Although Simple Techniques (V075) found no significant differences on this chart it showed significant effects till moderate extents and some from great to very great extents, moderate levels showed no trends / transitions (p. 204).

Meaning:

1) From A, two poles of understanding exist - it appears there are two established definitions of lean.
2) From D, the many differences by competitive advantage grouping imply the different definitions of lean produce different outcomes (perceived advantage or success).
3) From B, additional learning is associated to the developing of the new, more advantageous concepts on lean.
4) Although (C) familiarity and experience (D) go part the way to addressing the differences in understanding, competitive advantage (E) gives further adjustment. The differences for providing competitive advantage are not identified by current means of learning (including experiential learning). This indicates further learning tools are required to support practitioners.

Those with greater knowledge and experience with lean think of and apply lean differently than those who don't. Even more so those who consider lean a greater competitive advantage and as inferred those who gain a greater advantage from lean think differently about lean.

13.1.4 Comparing Key Variables

The following charts make comparison between familiarity with (knowledge of) lean, lean implementation experience and an impression of lean's benefits (specifically whether lean provides a competitive advantage). Logically the more experience participants had with lean the stronger their understanding of lean is. A strong near 1:1 linear relationship ($r^2 = 0.6$) is seen in Figure 232. The other key variable is the extent participants thought lean to be competitive advantage. Figure 233 and Figure 234 are similar plots taking competitive advantage as the output (dependent) variable and familiarity and implementation experience as the input (independent) variable. For these plots the linear relationship is not as strong however the correlation is made clear by viewing the means plots and ANOVA (Figure 234 and Figure 236) showing both $F(1,\sim140) \sim 30$, $p < 0.00001$.

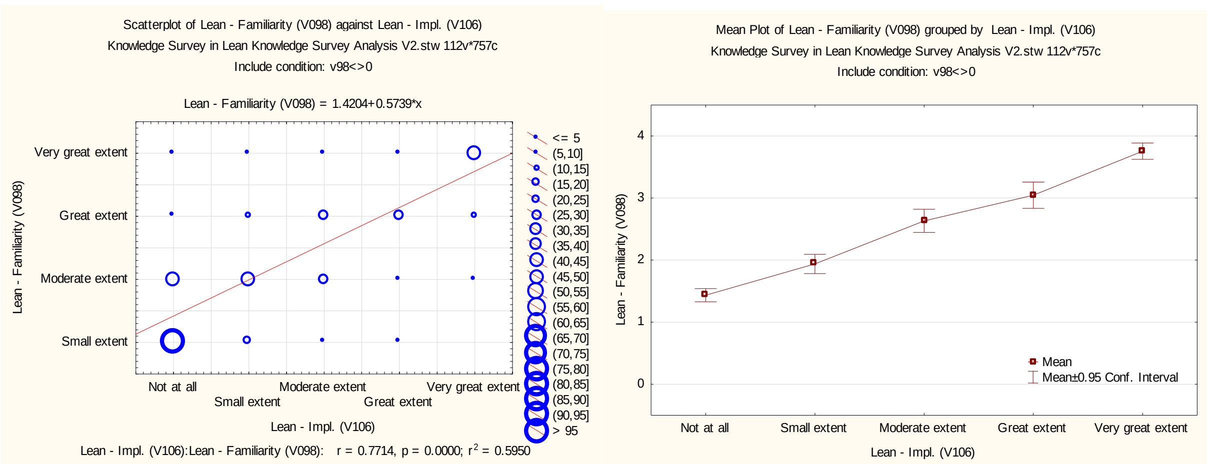

Figure 232 Familiarity with lean by Experience with lean implementation—scatter plot with means plot (95% CI).

It is significant that as lean knowledge and experience increases so do the appreciation of its benefits as a competitive advantage. If there were significant flaws in the approach, e.g. if lean was a fad only, then it would be expected that the advantage plots would noticeably plateau or show a decrease. The opposite is clear. The more knowledge and experience is had with lean the leaner is appreciated as providing a competitive edge.

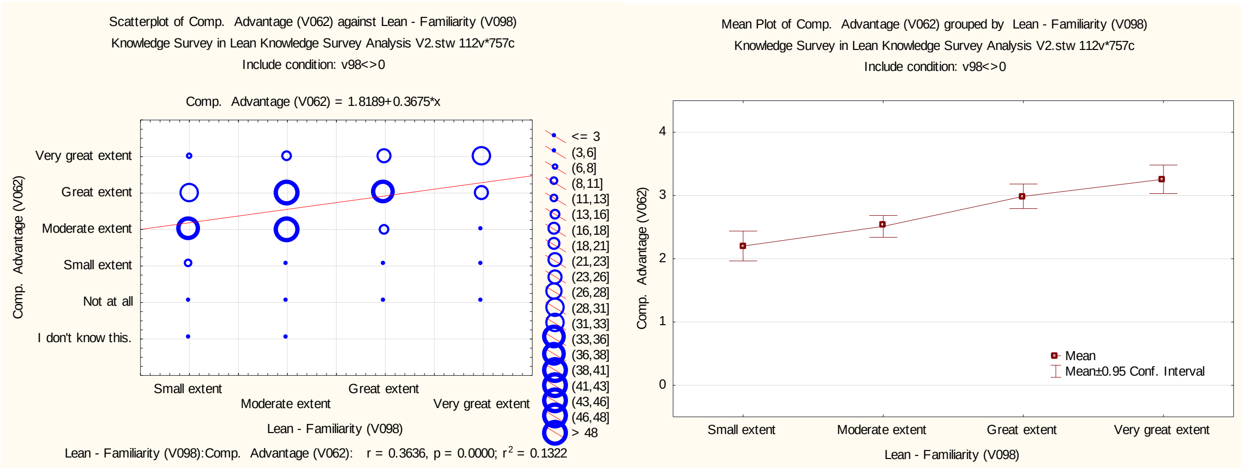

Figure 233 Competitive advantage of lean by Familiarity with lean —scatter plot with means plot (95% CI, 0 = Not at all, 4 = Very great extent).

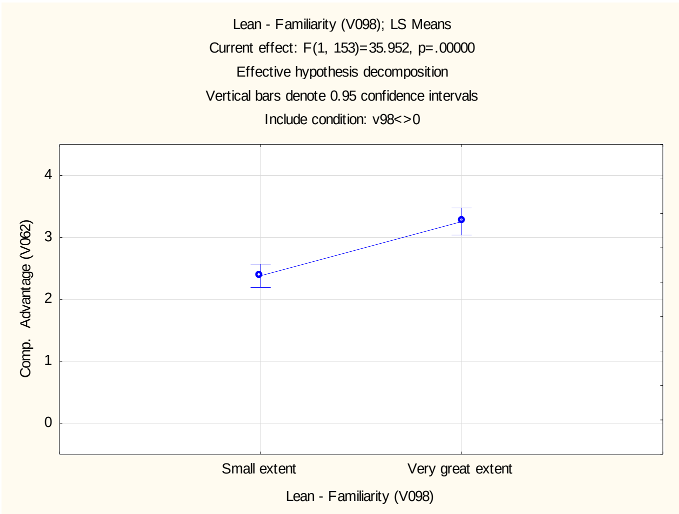

Figure 234 Competitive advantage of lean by Familiarity with lean –ANOVA , highly significant p < 0.00001 (F1,153)=36.0 (0 = Not at all, 4 = Very great extent)

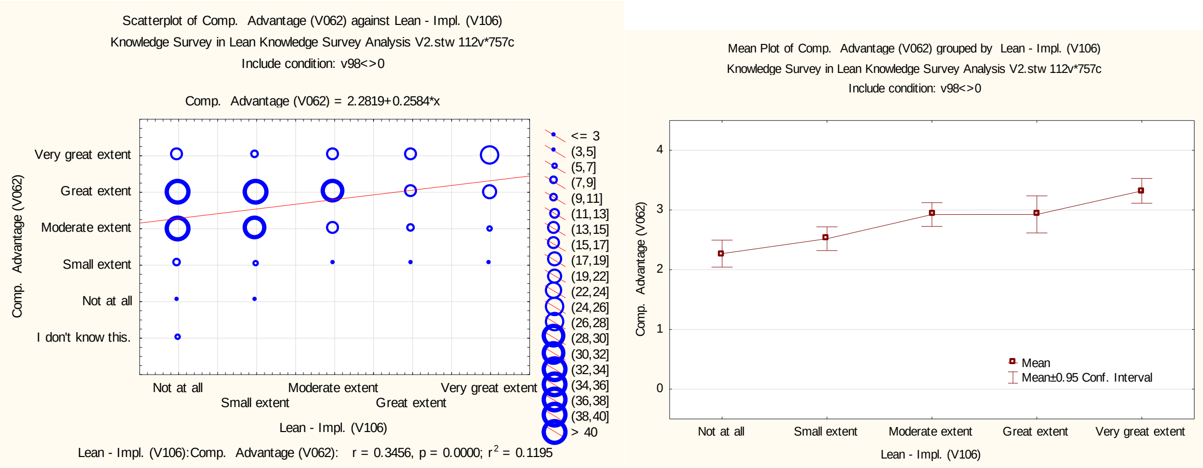

Figure 235 Competitive advantage of lean by Experience with lean implementation—scatter plot with means plot (95% CI, 0 = Not at all, 4 = Very great extent).

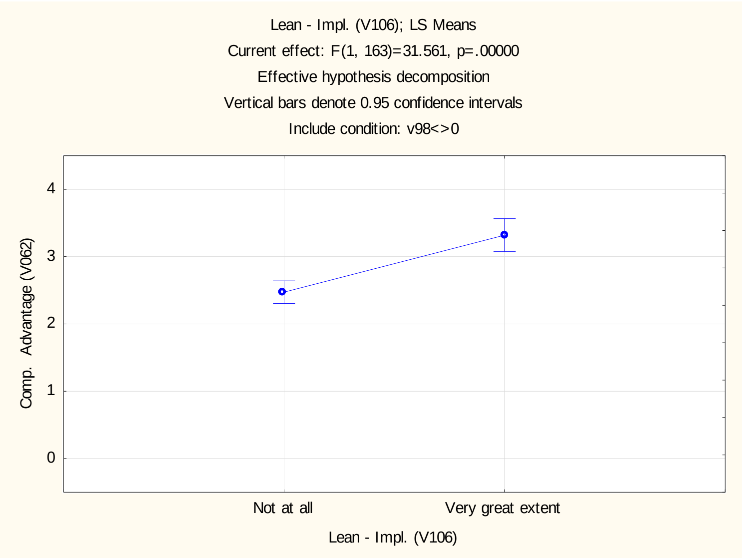

Figure 236 Competitive advantage of lean by Experience with lean implementation –ANOVA, highly significant p < 0.00001 F(1,163)=31.5. (0 = Not at all, 4 = Very great extent)

13.1.5 Factor Analysis (EFA/CFA)

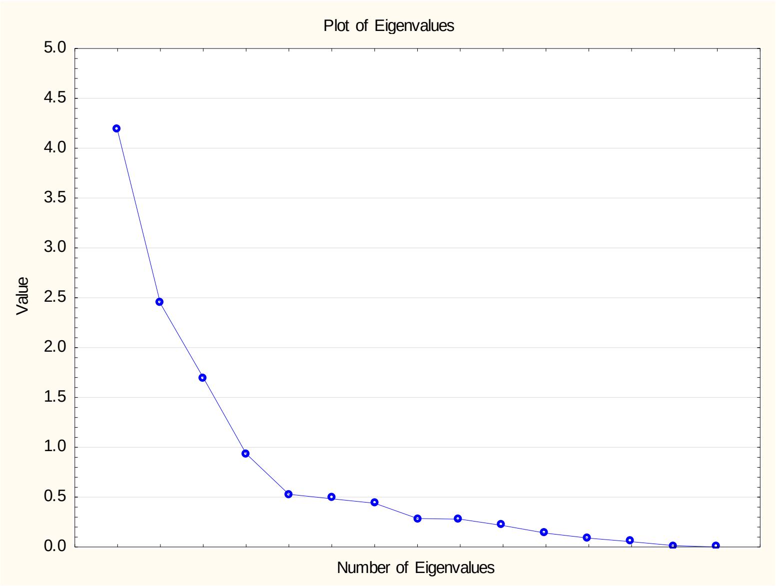

Figure 237 Scree plot for principal axis factoring iteration 0.

	Factor (1)	Factor (2)	Factor (3)	Factor (4)
V062 Comp. Advantage	-0.54	0.13	0.17	-0.05
V098 Lean Familiarity	-0.63	0.27	-0.18	-0.32
V106 Lean Impl.	-0.64	0.23	-0.24	-0.40
V050 Repacking of JIT/Qual. Sys	0.00	-0.56	-0.23	-0.13
V051 Tools or processes	-0.28	-0.27	0.02	0.28
V052 Process Eng.	0.09	-0.70	-0.17	0.06
V053 Waste Elimin.	-0.58	-0.12	0.03	0.24
V054 Train and Empower	-0.79	0.00	-0.14	0.14
V055 Fragile/ Unbuffered	-0.20	-0.49	-0.10	-0.19
V056 New Systems/Ways	-0.44	-0.28	0.11	0.27
V057 Respecting People	-0.72	0.00	-0.20	0.10
V058 Philos. / Strategy	-0.63	-0.01	-0.12	0.15
V059 Needs regularity and focus	-0.57	-0.02	-0.20	-0.07
V060 New label Indus. Eng.	-0.05	-0.72	-0.18	-0.17
V067 Large impact	-0.18	-0.19	-0.04	-0.20
V068 Best Methods	-0.10	-0.24	0.51	-0.05
V069 Comm. Process	-0.27	-0.03	0.62	-0.16
V070 Staff Identity	-0.13	-0.15	0.57	-0.25
V071 Small and regular	-0.27	0.04	0.43	-0.06
V072 Key Staff Only	0.13	-0.31	-0.08	-0.10
V073 Mgmt Force	-0.06	-0.38	0.02	-0.18
V074 Technology	0.16	-0.44	0.20	0.11
V075 Simple Techniques	-0.28	0.02	0.23	-0.13
V064 The extent that a manager understands Lean is critical for success.	-0.35	-0.06	0.21	0.29
V065 In a small organisations management's understanding is top priority for success.	-0.33	-0.10	0.13	0.11
V116 Work Experience (~Likert)	-0.09	0.09	-0.05	0.12
Expl.Var	4.18	2.44	1.70	0.94
Prp.Totl	0.16	0.09	0.07	0.04

Factor Loadings (Unrotated) Extraction: Principal axis factoring (Marked loadings are >.300000)

Figure 238 Unrotated factor loadings for principal axis factoring iteration 0.

	Factor (1)	Factor (2)	Factor (3)
V098 Lean Familiarity	0.64	0.24	0.13
V106 Lean Impl.	0.63	0.21	0.17
V062 Comp. Advantage	0.54	0.12	-0.19
V050 Repacking of JIT/Qual. Sys	-0.02	-0.56	0.21
V051 Tools or processes	0.26	-0.28	-0.01
V052 Process Eng.	-0.09	-0.70	0.15
V053 Waste Elimin.	0.57	-0.15	-0.03
V054 Train and Empower	0.79	-0.03	0.13
V055 Fragile/ Unbuffered	0.21	-0.50	0.06
V056 New Systems/Ways	0.40	-0.28	-0.09
V057 Respecting People	0.72	-0.03	0.19
V058 Philos. / Strategy	0.64	-0.04	0.10
V059 Needs regularity and focus	0.60	-0.05	0.17
V060 New label Indus. Eng.	0.03	-0.69	0.15
V068 Best Methods	0.10	-0.26	-0.56
V069 Comm. Process	0.26	-0.03	-0.65
V070 Staff Identity	0.13	-0.14	-0.58
V071 Small and regular	0.25	0.03	-0.43
V072 Key Staff Only	-0.15	-0.29	0.08
V073 Mgmt Force	0.04	-0.36	-0.03
V074 Technology	-0.18	-0.44	-0.20
V075 Simple Techniques	0.26	0.02	-0.23
Expl.Var	3.89	2.33	1.62
Prp.Totl	0.18	0.11	0.07

Factor Loadings (Unrotated) Extraction: Principal axis factoring (Marked loadings are >.300000)

Figure 239 Unrotated factor loadings for principal axis factoring non-discriminant (partial iteration).

	Second (1)	Factor (1)	Factor (2)	Factor (3)
V098 Lean Familiarity	**0.30**	0.58	**-0.22**	-0.10
V106 Lean Impl.	**0.28**	0.58	-0.17	-0.13
V062 Comp. Advantage	0.36	0.39	-0.15	*0.19*
V050 Repacking of JIT/Qual. Sys	-0.05	0.02	0.59	-0.08
V051 Tools or processes	0.16	*0.19*	**0.27**	0.08
V052 Process Eng.	-0.06	-0.07	0.72	-0.02
V053 Waste Elimin.	0.34	0.45	0.14	0.10
V054 Train and Empower	0.40	0.69	0.05	-0.04
V055 Fragile/ Unbuffered	0.13	0.16	0.50	0.06
V056 New Systems/Ways	**0.27**	**0.28**	**0.25**	0.16
V057 Respecting People	0.34	0.66	0.06	-0.10
V058 Philos. / Strategy	0.33	0.56	0.06	-0.02
V059 Needs regularity and focus	**0.28**	0.54	0.08	-0.08
V060 New label Indus. Eng.	0.01	0.04	0.71	-0.01
V068 Best Methods	**0.26**	-0.11	0.15	0.54
V069 Comm. Process	0.36	0.00	-0.10	0.59
V070 Staff Identity	**0.27**	-0.09	0.03	0.53
V071 Small and regular	**0.28**	0.07	-0.12	0.39
V072 Key Staff Only	-0.09	-0.12	**0.30**	-0.03
V073 Mgmt Force	0.05	0.00	0.35	0.09
V074 Technology	-0.01	**-0.24**	0.39	**0.23**
V075 Simple Techniques	**0.22**	0.14	-0.07	**0.22**
Expl.Var	3.77	3.77	2.31	1.78
Prp.Totl	0.17	0.17	0.10	0.08

Correlation Between Oblique Factors:				
	Factor 1	1.00		
	Factor 2	-0.03	1.00	
	Factor 3	***0.27***	0.02	1.00

Factor Loadings (Varimax raw) Extraction: Principal axis factoring (Marked loadings are >.300000, **Bold** > 0.2, *Italics* ~0.2)

Figure 240 Factor loadings and correlations for hierarchical analysis of oblique factors non-discriminant (partial iteration).

	Factor (1)	Factor (2)	Factor (3)
V098 Lean Familiarity	-0.64	0.10	0.23
V106 Lean Impl.	-0.64	0.04	0.22
V050 Repacking of JIT/Qual. Sys	-0.01	-0.57	-0.21
V052 Process Eng.	0.07	-0.58	-0.39
V054 Train and Empower	-0.75	-0.07	0.09
V055 Fragile/ Unbuffered	-0.24	-0.43	-0.36
V057 Respecting People	-0.75	-0.13	0.09
V058 Philos. / Strategy	-0.65	-0.09	0.06
V059 Needs regularity and focus	-0.63	-0.15	0.02
V060 New label Indus. Eng.	-0.09	-0.62	-0.42
V068 Best Methods	-0.06	0.25	-0.55
V069 Comm. Process	-0.26	0.50	-0.52
V070 Staff Identity	-0.11	0.32	-0.52
V071 Small and regular	-0.24	0.40	-0.34
V075 Simple Techniques	-0.26	0.24	-0.28
Expl.Var	3.03	1.93	1.66
Prp.Totl	0.20	0.13	0.11

Factor Loadings (Unrotated) Extraction: Principal axis factoring (Marked loadings are >.300000)

Figure 241 Unrotated factor loadings for principal axis factoring final iteration.

	Second (1)	Factor (1)	Factor (2)	Factor (3)
V098 Lean Familiarity	**0.24**	0.62	-0.18	-0.02
V106 Lean Impl.	**0.23**	0.62	-0.13	-0.04
V050 Repacking of JIT/Qual. Sys	-0.04	0.02	0.59	-0.15
V052 Process Eng.	-0.03	-0.09	0.70	-0.03
V054 Train and Empower	**0.29**	0.70	0.04	0.01
V055 Fragile/ Unbuffered	0.11	0.17	0.57	0.07
V057 Respecting People	**0.28**	0.71	0.09	-0.03
V058 Philos. / Strategy	**0.25**	0.60	0.07	0.00
V059 Needs regularity and focus	**0.24**	0.59	0.14	-0.01
V060 New label Indus. Eng.	0.03	0.04	0.75	-0.01
V068 Best Methods	0.18	-0.12	0.11	0.56
V069 Comm. Process	**0.29**	0.04	-0.10	0.70
V070 Staff Identity	**0.20**	-0.07	0.04	0.58
V071 Small and regular	**0.23**	0.08	-0.12	0.51
V075 Simple Techniques	**0.20**	0.13	-0.02	0.38

Correlation Between Oblique Factors:				
	Factor 1	1.00		
	Factor 2	0.07	1.00	
	Factor 3	*0.14*	-0.06	1.00

Hierarchical Analysis of Oblique Factors: Secondary & Primary (Unique) Factor Loadings (Marked loadings are >.300000. Bold > 0.2)

Figure 242 Factor loadings and correlations for hierarchical analysis of oblique factors final iteration.

Value	Eigenvalue	% Total	Cumulative Eigen Value	Cumulative %
1	3.1	21.0	3.15	21.0
2	1.9	12.9	5.09	33.9
3	1.7	11.2	6.77	45.1
4	0.7	4.6	7.47	49.8

Figure 243 Eigen values and % of variance explained, principal axis factoring if 4 factors extracted (final iteration).

	Factor (1)	Factor (2)	Factor (3)		Factor (1)	Factor (2)	Factor (3)
V098 Lean Familiarity	0.67	0.27	0.16		0.70	**-0.23**	-0.03
V106 Lean Impl.	0.66	0.23	0.20		0.70	*-0.18*	-0.07
V062 Comp. Advantage	0.59	0.14	-0.21		0.53	-0.18	**0.33**
V050 Repacking of JIT/Qual. Sys	-0.01	-0.63	0.26		0.01	0.67	-0.12
V051 Tools or processes	0.30	-0.34	0.00		**0.27**	**0.34**	0.14
V052 Process Eng.	-0.09	-0.74	0.18		-0.09	0.76	-0.05
V053 Waste Elimin.	0.62	-0.17	-0.01		0.59	0.17	**0.21**
V054 Train and Empower	0.80	-0.02	0.16		0.81	0.05	0.06
V055 Fragile/ Unbuffered	0.24	-0.57	0.09		**0.22**	0.58	0.09
V056 New Systems/Ways	0.45	-0.32	-0.09		0.39	**0.30**	**0.26**
V057 Respecting People	0.75	-0.02	0.23		0.78	0.07	-0.02
V058 Philos. / Strategy	0.69	-0.04	0.14		0.70	0.07	0.05
V059 Needs regularity and focus	0.65	-0.04	0.21		0.67	0.09	-0.02
V060 New label Indus. Eng.	0.04	-0.73	0.18		0.04	0.75	-0.01
V068 Best Methods	0.11	-0.30	-0.64		-0.07	0.16	0.69
V069 Comm. Process	0.28	-0.04	-0.71		0.09	-0.10	0.75
V070 Staff Identity	0.14	-0.17	-0.68		-0.04	0.03	0.71
V071 Small and regular	0.29	0.04	-0.55		0.14	-0.14	0.59
V072 Key Staff Only	-0.18	-0.37	0.10		-0.16	**0.38**	-0.07
V073 Mgmt Force	0.04	-0.46	-0.03		0.01	0.45	0.13
V074 Technology	-0.20	-0.52	-0.24		**-0.28**	0.46	**0.28**
V075 Simple Techniques	0.31	0.04	-0.32		**0.22**	-0.10	**0.38**
Expl.Var	0.31	0.04	-0.32		4.30	2.93	2.42
Prp.Totl	4.48	3.01	2.24		0.20	0.13	0.11

Factor Loadings Extraction: Principal Components (Marked loadings are >.300000, in rotated matrix Bold > 0.2, Italics ~0.2)

Figure 244 Factor loadings for principal components partial iteration.

	Unrotated				Rotated		
	Factor (1)	Factor (2)	Factor (3)		Factor (1)	Factor (2)	Factor (3)
V098 Lean Familiarity	-0.70	-0.04	-0.21		0.69	-0.01	**-0.24**
V106 Lean Impl.	-0.67	0.03	-0.17		0.67	-0.05	-0.17
V050 Repacking of JIT/Qual. Sys	0.05	0.49	0.48		0.01	-0.09	0.68
V052 Process Eng.	0.12	0.53	0.60		-0.05	-0.05	0.81
V053 Waste Elimin. (V053)	-0.62	0.04	0.22		0.61	0.19	0.15
V054 Train and Empower	-0.81	0.11	0.01		0.82	0.02	0.01
V057 Respecting People	-0.78	0.15	0.00		0.80	-0.02	0.03
V058 Philos. / Strategy	-0.72	0.10	0.09		0.72	0.07	0.07
V059 Needs regularity and focus	-0.70	0.17	0.05		0.72	-0.01	0.10
V060 New label Indus. Eng.	-0.01	0.56	0.60		0.08	-0.05	0.82
V068 Best Methods	-0.01	-0.52	0.57		-0.08	0.75	0.12
V069 Comm. Process	-0.19	-0.72	0.37		0.07	0.81	-0.17
V070 Staff Identity	-0.07	-0.56	0.46		-0.02	0.73	0.01
V071 Small and regular	-0.21	-0.60	0.28		0.11	0.66	-0.17
V072 Key Staff only	0.17	0.21	0.34		-0.14	0.03	0.40
Expl.Var	3.73	2.43	1.95		3.70	2.26	2.14
Prp.Totl	0.25	0.16	0.13		0.25	0.15	0.14

Factor Loadings Extraction: Principal Components (Marked loadings are >.300000, in rotated matrix Bold > 0.2, Italics ~0.2)

Figure 245 Factor loadings for principal components final iteration.

Value	Eigenvalue	% Total	Cumulative Eigen Value	Cumulative %
1	3.7	24.9	3.73	24.9
2	2.4	16.2	6.16	41.1
3	1.9	13.0	8.10	54.0

Figure 246 Eigen values and % of variance explained (principal axis factoring) if 4 factors are extracted (final iteration).

13.1.6 Structural Equation Modelling

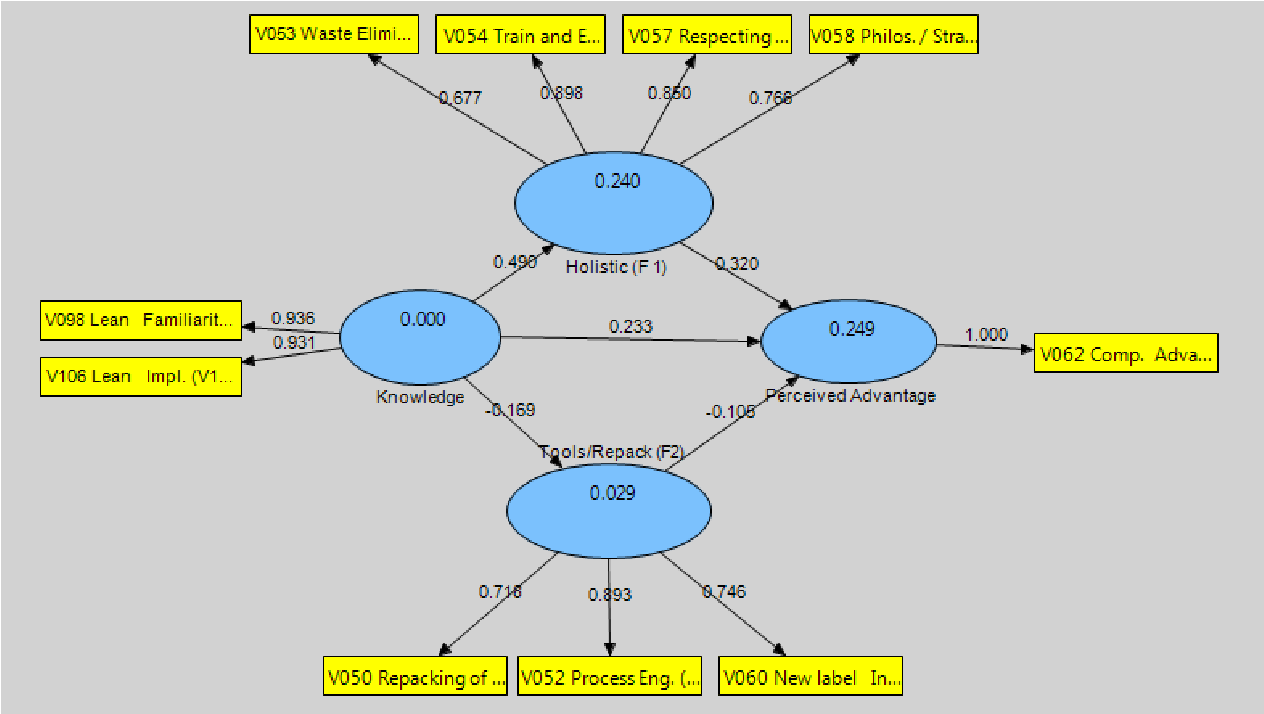

Figure 247 The impact of lean knowledge on understanding and advantage: path model, including measurement loadings.

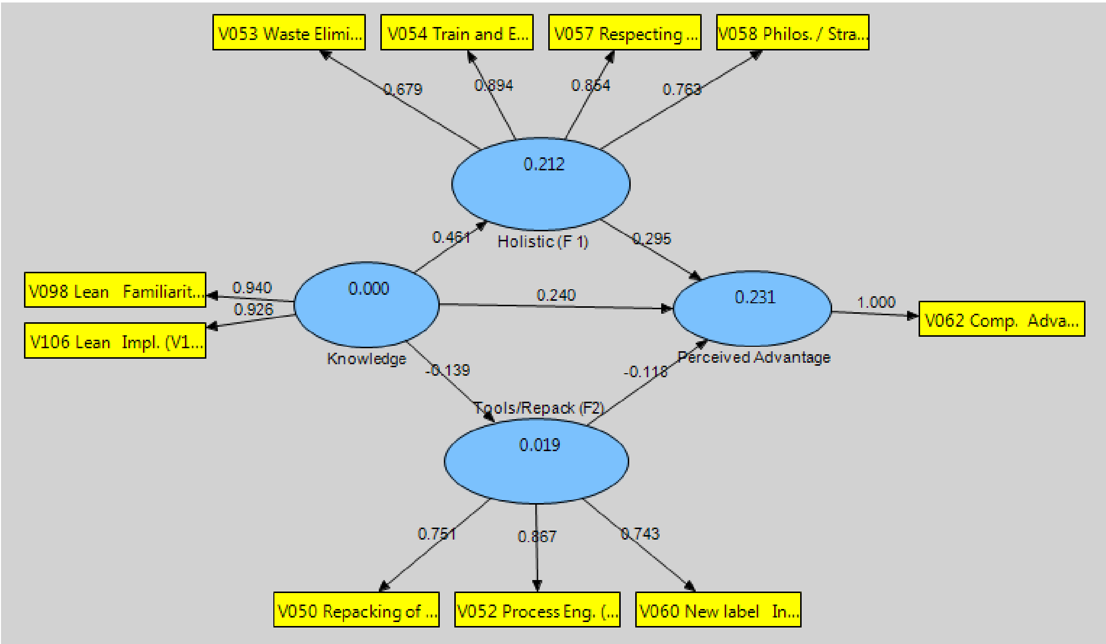

Figure 248 The impact of lean knowledge on understanding and advantage: path model, including measurement loadings (268 cases, 90% missing data case-wise replaced[202]).

[202] Mean-wise replacement was trialed but showed weaker effects on the low significance path, Tool/Repack > Comp. Adv.

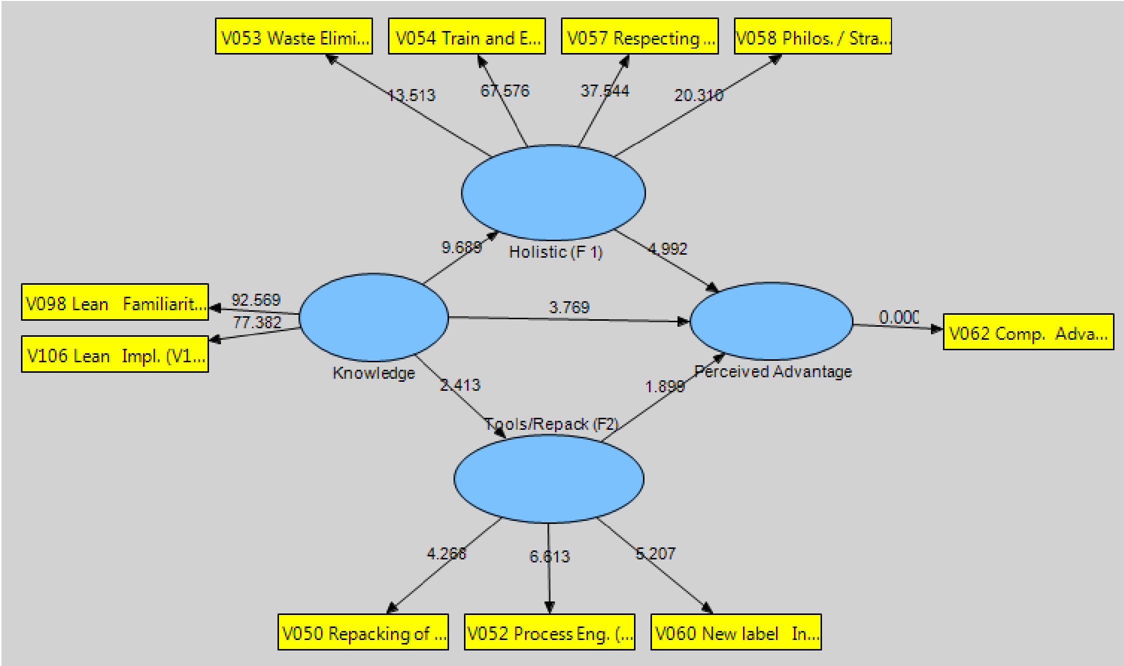

Figure 249 The impact of lean knowledge on understanding and advantage: boot strapped path model showing T-statistic (5000 iterations, 268 cases 90% complete, case-wise replacement, individual sign changes allowed). Significant t-values are 1.65 for 10% (p=0.1), 1.96 for 5% (p=0.05), 2.58 for 1% (p=0.01).

13.1.7 Textural Responses

Approach

Throughout the survey, room was left for textural responses to allow freedom for expression of participant's opinion. Similar responses[203] were "coded" and tallied for frequency. These tables are included below. A pragmatic approach was taken to coding, i.e. anything of frequency or particular relevance was tallied. Some only resulted in single occurrences but still were included in the tables for interest although not statistically significant.

Coded Responses

Pursuit of lean Knowledge: Why and Why not?

The highest responses were found for early textural questions. Two reasons for this are the participants were not as fatigued by the survey early on and the participants were strongly prompted for their comments to the first textural questions. These first textural questions asked why participants had or had not pursued more lean knowledge. These questions were presented to participants selectively i.e. depending on answers to familiarity with lean.

Top responses for not pursuing more knowledge of lean were feelings of lean being irrelevant, not being aware of lean, not having time to learn, lack of awareness to its relevance, or not required by the employer (Figure 250). Absolute ignorance to lean's existence results in the first level of failure to lean being utilised.

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[203] Responses tallied for first 519 participants only.

The lack of time for learning is a common reason for not investigating new ways or technologies. There is a mind-set that is prone to working and not to thinking about improving or allowing time to develop necessary skills and new competencies. “Time is money” and when finances are tight and business performance needs raising there is a “leap of faith” needed to pause the current necessary activities of business in order to develop new competencies especially those more abstract than current practice. This is particularly true for small businesses where the senior management team is highly integrated in day to day operations.

Context: Lean familiarity ="not at all" to "moderate extent", Question = Why haven't you pursued more Lean knowledge?		
Total of responses coded:	**217**	
Coded Response	**Frequecy**	**% of total**
Not relevant to my field	74	34.1%
Did not know about it	65	30.0%
No time to learn	22	10.1%
other	18	8.3%
Unaware how it can help my field	18	8.3%
I am not required to by my employer	18	8.3%
Business is too small	7	3.2%
Working on something else e.g. TQM, six sigma, TOC	5	2.3%
Use other experts for these things	4	1.8%
Cost to implement	4	1.8%
Cost of training	4	1.8%
Had bad feedback from others (Lean is a fad)	3	1.4%
Variation in product make difficult	3	1.4%
learn as I need/ go	2	0.9%
In aerospace safety/ reliability is important not lean	1	0.5%
Could not get others invovled	1	0.5%
Same as other old CI methods	1	0.5%
Survey advice	1	0.5%
Aware but not investigated	1	0.5%
with Lean Six-sigma)	1	0.5%
Not relevant, is just cost cutting	1	0.5%
Availability of learning tools low	1	0.5%

Figure 250 Tabulated textural responses: context—lean familiarity ="not at all" to "moderate extent", Question = Why haven't you pursued more lean knowledge?

The top reason given for not pursuing lean knowledge was “Lean is not relevant to my field”. As zealots for lean systems thinking, it is hard to believe that lean is not relevant to the fields represented (or any field). It is understandable that lean is simpler for and delivers more significant results in certain situations. Lean is now commonly used in many areas beyond manufacturing and mass production including service industries, healthcare and education (“Lean universities”) as well as lean government. Figure 53 show the industries covered by “Lean is not relevant to my field” participants. Significantly represented are engineering and manufacturing categories (30% combined). More strikingly is the negative “Lean is not relevant to my field” response was largely uninformed. See Figure 54, a histogram for lean familiarity of participants who answered lean as not relevant for my field. 46% of the participants who emphatically stated lean is not relevant to their field also self-reported they actually had no familiarity with lean at all. Their negative response to relevance of lean had no basis (according to self-report). This obviously is a significant barrier to lean uptake. That this kind of uninformed avoidance pervades amongst those with no knowledge of lean similar biases to pursuing lean and other methods must exist at other levels. Further interesting responses included “I am not required by my employer” (8%) showing passivity and various responses showing lack of understanding of lean and application beyond manufacturing and mass production. Included were 3 persons who had avoided lean because of others bad experiences. ***To increase the success of lean, lean would need to be appropriately marketed to the above categories of persons.***

Context: Lean familiarity ="Great extent" to "Very great extent", Question = Why did you pursue Lean knowledge?		
Total participant responses coded:	**77**	
Coded Response	**Frequecy**	**% of total**
Benfits to business performance/ waste reuction	23	29.9%
Introduced by employer	22	28.6%
Strong personal pursuit with recognition of Lean's benefits and a desire to further own knowledge	14	18.2%
Known as a required skill for consulting or other career progression	7	9.1%
Seeking staff /staff morale enhancement	5	6.5%
Part of study/ training program	5	6.5%
Want to empower people -a way to invovle entire organisation in CI	4	5.2%
Other	3	3.9%
Seen as essential to business or its survival	3	3.9%
Important for process improvement	3	3.9%
Way to introduce CI / problem solving	3	3.9%
Is a logical process	2	2.6%
Safety	1	1.3%
Popular method	1	1.3%
General supply chain involvement	1	1.3%
Customer introduction	1	1.3%
Understand why it fails	1	1.3%
Keep up to date	1	1.3%
Supplier introduction	1	1.3%

Figure 251 Tabulated textural responses: context—lean familiarity ="Great extent" to "Very great extent”, Question = Why did you pursue lean knowledge?

The reasons for lean knowledge uptake were also coded (Figure 251). Due to demographics of sample there were not as many responses here although still of statistically significant size. Seeking improvement in business performance was the most frequented response (30%). Close second was by introduction from an employer (29%). This was followed by those who had personally pursued lean to better their ability to perform in their role (18%) more so than just viewing lean as a required skill (9%). Surprisingly low was the influence of study programs (e.g. MBA or other degree) in exposing participants to lean (6.5%). Other lower frequency was the desire specifically to empower people, lift staff morale, or introduce continuous improvement culture. ***To increase the success of lean, these positive aspects need to be fostered. A special focus should be a strong advance of lean thinking in education programs. Lean uptake is obviously sparse across the board with lean knowledge coming in “as needed” basis by “self-pursuit” or mistake far more than being responsibly provided in tertiary institutions. Truth is most of those in the education field have no or an inadequate knowledge of lean and are focused on old management methods.***

Lean is a Competitive Advantage Context

The coded comments following the question "To what extent does lean provide a competitive advantage?" are included as Figure 252. The quantity of responses was lower (50) dropping the statistical significance but provided insights. Responses that lean is not sufficient in itself (12%) emphasised clarity around the question. lean will only provide a competitive advantage to the extent that competition is not applying lean and it is a point of difference. In some industries (e.g. automobile), the uptake of lean has been high and therefore is a core competency rather than a competitive edge. A competitive edge may be found in another marketing point including the degree of success and innovation in the application of lean.

Context: Comment regarding question - To what extent is Lean a competitive advantage?		
Total participant responses coded:	**50**	
Coded Response	**Frequecy**	**% of total**
Other =miscelaneous and/ or irrelevant comments	9	18.0%
Lean is insufficient in itself (core competency)	6	12.0%
Lean is suited to any business or industry	6	12.0%
Lean needs a holistic approach /all invovled	4	8.0%
Needs to be applied correctly (LAME)	3	6.0%
We do many things Lean just don't call it lean	3	6.0%
Management commitment required	3	6.0%
Strategy required	2	4.0%
If everyone implements Lean it is not a point of difference	2	4.0%
not applicable to all processes	2	4.0%
Lean = cut fat = cut staff	2	4.0%
Old concepts brought back nothing new	1	2.0%
Is better for larger organisations	1	2.0%
One of many tools	1	2.0%
Change the language to suit (not strange Japanese)	1	2.0%
Long term commitment	1	2.0%
Kills innovation (cost cutting)	1	2.0%
When everyone doing Lean important how well you do it	1	2.0%
Suitable in manufacturing/logistics only	1	2.0%
Advantage dependent on product mix etc.	1	2.0%
A marketing point to customers	1	2.0%
Difficult in small team/business to make big changes	1	2.0%
How can I apply it to design?	1	2.0%
employees not engaged	1	2.0%
Aerospace is about safety so Lean not as applicable	1	2.0%
Expensive to apply - costs a lot - e.g lean experts	1	2.0%

Figure 252 Tabulated textural responses: context—comment regarding the question - To what extent is lean a competitive advantage?

Application concerns were raise in the need for a holistic approach (8%), and the correct application (6%). Specifically lean implementation is described as LAME i.e. lean Applied Misappropriately Everywhere. Other comments include the feeling that "we do many things lean" but don't call it lean. Piecemeal lean usage is common but not associated with true success as the holistic approach, embracing and understanding the core concepts. Other misconceptions appear e.g. lean is cost cutting, is dependent on product mix (e.g. suited to high-volume with low-mix) and does not support reliability or safety. Concerns for small business were also raised as discussed throughout this work.

These results both provide more insights for education and the focus on providing a competitive advantage through lean is shifting to lean becoming an essential core competency in manufacturing. How quickly this spreads to becoming the standard in other industries is yet to be seen.

Lean Implementation Focus Context

Only 25 textural responses were suitable for coding under the lean Implementation Focus section. Statistically percentages are not as significant. Top responses were to the importance of staff involvement (6, 24%), keeping initiatives smaller simple for continuous improvement (4, 16%), the pitfalls of staff involvements (4, 16%), the communication being a challenge to overcome, implementation needing to be both customised and holistic and the use of both small and large initiatives (2, 8% each).

Context: Implementation Focus		
Total participant responses coded:	**25**	
Coded Response	**Frequecy**	**% of total**
Staff involvement key	6	24%
Keep it small /simple for continuous improvement	4	16%
Pitfalls of staff invovlement (e.g. comments 1 x difficult in practice, 1x sometimes poorly implemented, 2 x decisions are for managemnt)	4	16%
Communication a challenge	3	12%
Other	2	8%
Small and large improvements	2	8%
Implementation customised/ not one way	2	8%
Must be comprehensive- many aspects to consider	2	8%
Costs too great for small company	1	4%
Need metrics	1	4%
Momentum	1	4%
More participants from staff initially	1	4%
Leadership invovlement important	1	4%
More training required	1	4%
Freezing change sometime necessay	1	4%

Figure 253 Tabulated textural responses: context—Implementation Focus.

The contrast between the importance of staff-involvement (i.e. all or majority of staff) and the pitfalls of staff involvement are of note. The respect for humans aspect of lean with staff involvement, training, and empowerment were identified as key factors throughout this work and strengthened by the analysis. Understanding how to carry this out amongst various situational variables is obviously important to success. Here four comments were seen. One participants mentioned the difficulty to actually carry this out in practice, another that it is often implemented poorly and two others debunked it that decisions are for managers. Further investigation in leading staff involvement, under different situations, would support practitioners greatly.

Other comments seen in Figure 253 are of interest but deemed to not bring new insight or statistical significance. One exception may be the comment that freezing change may sometimes be necessary. The comment indicates caution towards the top down approach but that it may be unavoidable in some circumstances. Much caution should be exercised in taking a top down approach due to the negative effects on staff engagement.

Management Understanding is Crucial Context

Context: Comment regarding: - Management knowledge/ understanding of Lean being crucial to implementation success		
Total participant responses coded:	**70**	
Coded Response	**Frequecy**	**% of total**
Other =miscelaneous and/ or irrelevant comments	17	24.3%
Don't know lean	17	24.3%
Management must take the lead	17	24.3%
Need all management and staff commited/ understanding	8	11.4%
Failure occurs without management commitment	4	5.7%
Lean is a tool. Should focus on startegic busines thinking/ planning as the prirotiy	4	5.7%
Doesn't have to be boxed as Lean- some do it intuitively	4	5.7%
Can't generalize regarding Lean	3	4.3%
Other factors may be key	3	4.3%
Lean is not necessary everywhere	2	2.9%
Lean is not all about the manager (but empowerment of others)	2	2.9%
Have never needed Lean in the past/ Lean is not the only way.	2	2.9%
Felt restricted by questions	1	1.4%
Always management is at fault	1	1.4%
Need to know where you are going so you can lead	1	1.4%
Inutitively statements are correct	1	1.4%
Small businesses may get away without but as the business grows (adds staff) you need philosophies more	1	1.4%
Small businesses are already Lean	1	1.4%
We failed until management drove lean	1	1.4%
Leadership and standard work are crucial and complimentary.	1	1.4%
Lean can be a fad	1	1.4%
Management must lead the changes	1	1.4%

Figure 254 Tabulated textural responses: context—comment regarding Management knowledge/understanding of lean being crucial to implementation success.

70 textural responses were coded in the context of management understanding being crucial (Figure 254). 17 responses (24%) were stated no knowledge of lean and another 17 contained miscellaneous and uninteresting comments. The most frequent feedback was strong confirmation that management must take the lead for lean implementation (17, 24%). This affirms the importance of management taking the lead in understanding lean (the context) in order to lead the implementation i.e. rather than leaving lean leadership to other staff or consultants. The next most frequent confirms management commitment but expands to all staff being involved in and understanding lean (8, 11%). Further 6% commented specifically that failure occurs without management commitment. One repeated view was that lean is a tool and management should focus on business strategy (4, 6%). This view ignores the strategic level of lean as a holistic system providing customer value. It indicates lean is tools to be applied in piecemeal fashion by the likes of consultants and production specialists without management bearing responsibility. Such an application of lean will not see sustained improvement or the true benefits of a highly aligned lean business and excellent learning organisation. A similarly dangerous view was lean doesn't have to be boxed that way and some do it

intuitively (4, 6%). Truly, lean can be presented under another name or integrated system. The danger is tending to neglect the holistic approach needed for success and statements indicate a piecemeal application and lack of the necessary commitment. Other interesting comments included that small businesses are already lean implying they don't need to apply lean, they have not needed lean before so why now (showing good performance is a reason for some not to try to do better), and that lean is considered a fad. One comment combined Leadership and standard work as key and complimentary for success.

13.1.8 Analysis of Introduced Bias

Various sample group biases were observed. The following presents significant biases observed and taken into account for results analysis and further discussion.

Sample Groups by Country Bias

A scatter plot of Sample Group by country gives indication of bias within country groupings, see Figure 255. Certain countries are represented stronger in certain sample groups than others

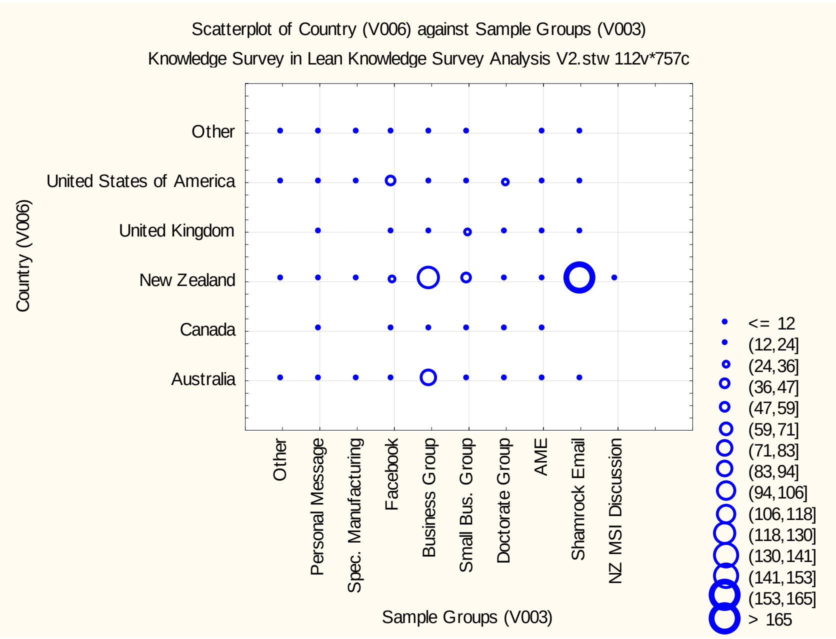


Figure 255 Sample Groups By Country (scatter plot).

Familiarity by Sample Group Bias

Above plots showed that certain countries were represented more in certain sample groups i.e. there non-homogeneous distribution of participants. Similarly, the understanding or familiarity with lean is different between these groups. This is clearly shown in the means plot of lean familiarity in Figure 256.

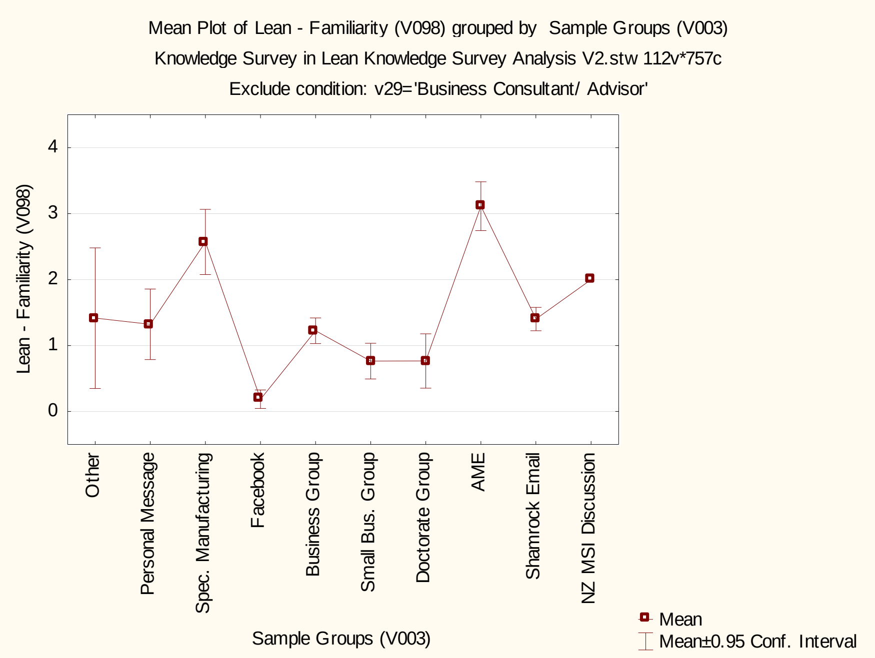


Figure 256 lean Familiarity by Participant Sample Groups Means Plots excluding Consultants/Advisors. Plot shows within group's bias.

Effect of Management Understanding of Lean on Implementation Success

The base question under this section was:

Lean is an organisational change. Do you agree with the following statements?

There were two statements:

"The extent that a manager understands lean and lean implementation is critical for the success of lean. Understanding what is critical governs their decision-making, ensuring greater chances of success."

"In a small organisation (say less than 50 staff) the management's understanding of lean should be the first and top priority to ensure an implementation is handled properly."

Figure 257 The effect of managements' understanding of lean on implementation success—histogram of V064 "The extent that a manager understands..." and V065 "In a small organisation management's understanding…" gives an overview of the number of observations and answers these questions. Figure 258 and Figure 262, Box plots categorised by familiarity with lean, show clearly as familiarity with lean increases so do mean responses. Means transition to strong agreement for both variables. This was typical of all key grouping variables.

"The extent that a manager understands…" shows general agreement across all participants with no significant differences by familiarity or implementation experience. Although arithmetic means plot shows a trend/difference for lean implementation, the adjusted LS means[204] (as used in the ANOVA plot) does not.

[204] The arithmetic mean is an average. The least squares mean is estimated from a linear model. They are adjusted for other terms in the model and are not as sensitive to missing values. They are theoretically a better estimate of the true population mean. This is why there is observed differences between some means plots and LS means plots.

The competitive advantage variable does show a small significant effect F(1,93)=5.6, p=0.02). See ANOVA LS means plots Figure 259, Figure 260, and Figure 261.

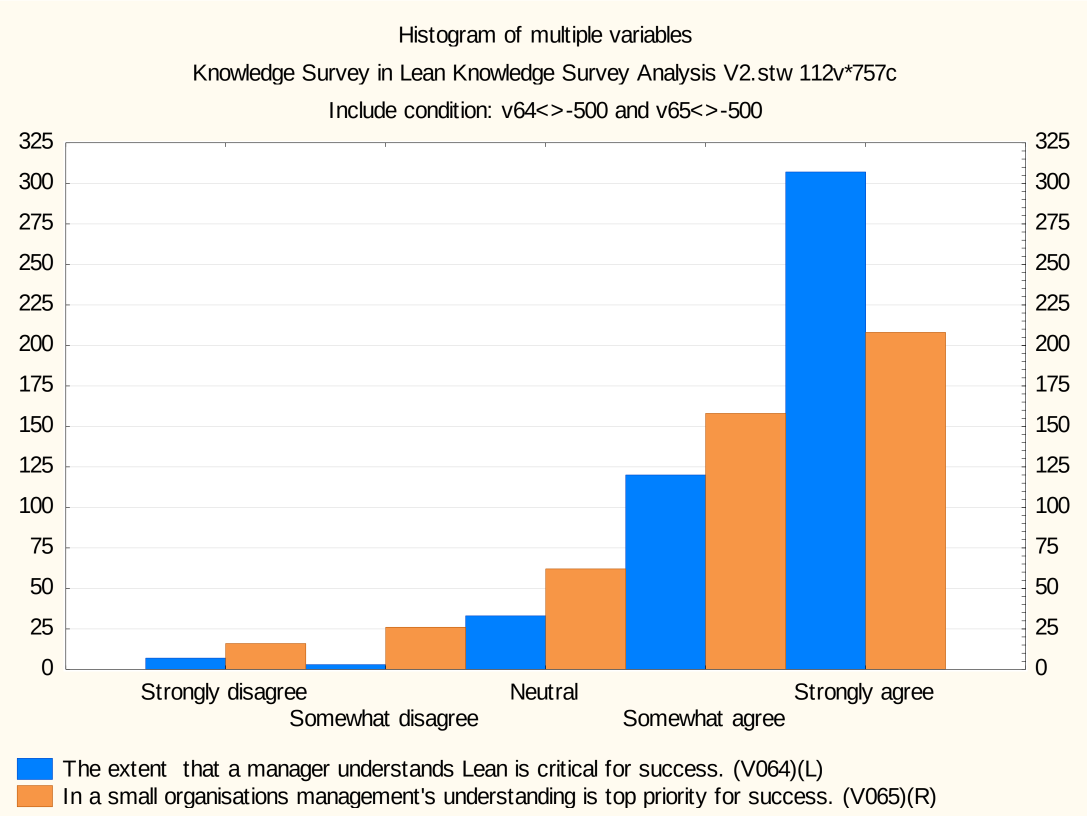


Figure 257 The effect of managements' understanding of lean on implementation success—histogram of V064 "The extent that a manager understands..." and V065 "In a small organisation management's understanding…"

"In a small organisation…" showed correlations for all variables (see Figure 263, Figure 264, and Figure 265). Familiarity was "borderline" at F(1,54)=3.6, p=.058, more data would likely show stronger significance but the effect is small. Implementation experience and competitive advantage gave stronger trends and statistics: F(1,171)=4.85, p=0.030 and F(1,93)=5.25, p=0.020. It is notable that competitive advantage again showed stronger correlation even though data set was smaller. This question was much more specific about the commitment a manager should make i.e. "understanding of lean should be the first and top priority". This emphasis led to more differences that are significant.

Although respondents who had no familiarity with lean answered across a wide range a good number still answered agree or strongly agree. These responses showed this is intuitive or trained in other disciplines.

There is support for the hypothesis with significant differences seen by grouping variables. There is also support for the tentative models emphasis on management learning being a critical part of lean implementation. The data showed stronger trends by competitive advantage and also where the question was more specific, calling for more commitment to learning.

It is important to note that this was an early exploratory analysis that looked at differences between the two extremes, small to very great rather than categorising into high and low. Significant effects were observed but are statistically weak because of the methodology.

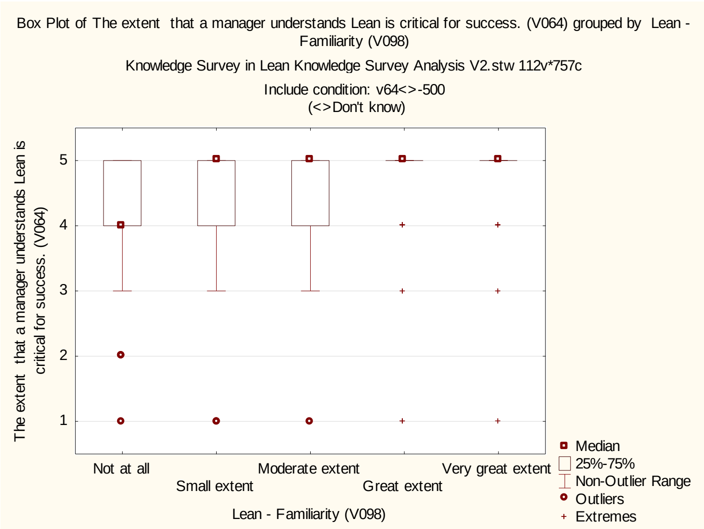


Figure 258 "The extent that management understands lean is critical for success" box plot by familiarity with lean (1= Disagree, 5 = Strongly agree).

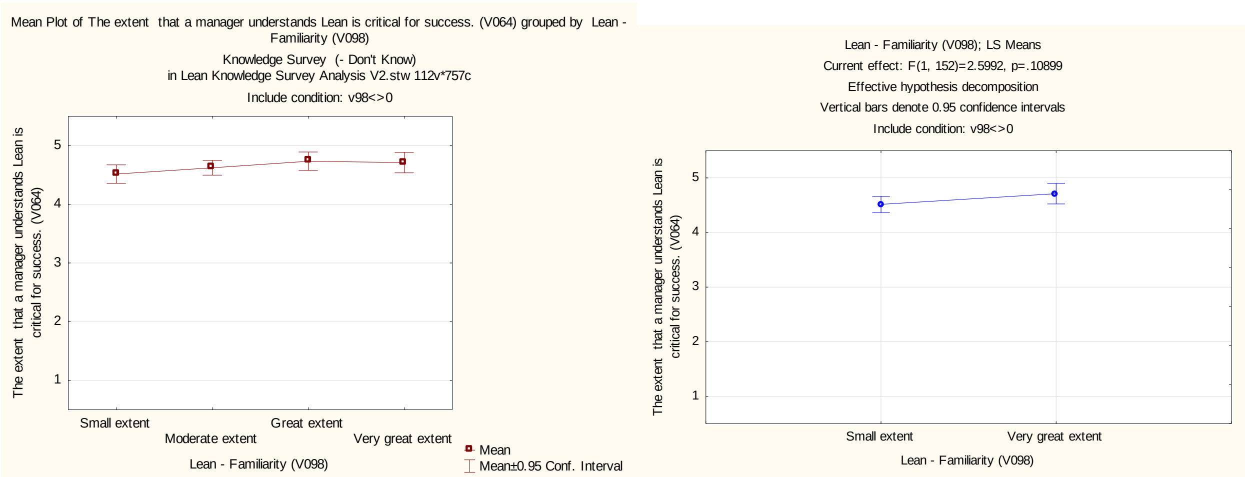


Figure 259 "The extent that management understands lean is critical for success" ANOVA by familiarity with lean (1= Disagree, 5 = Strongly agree).

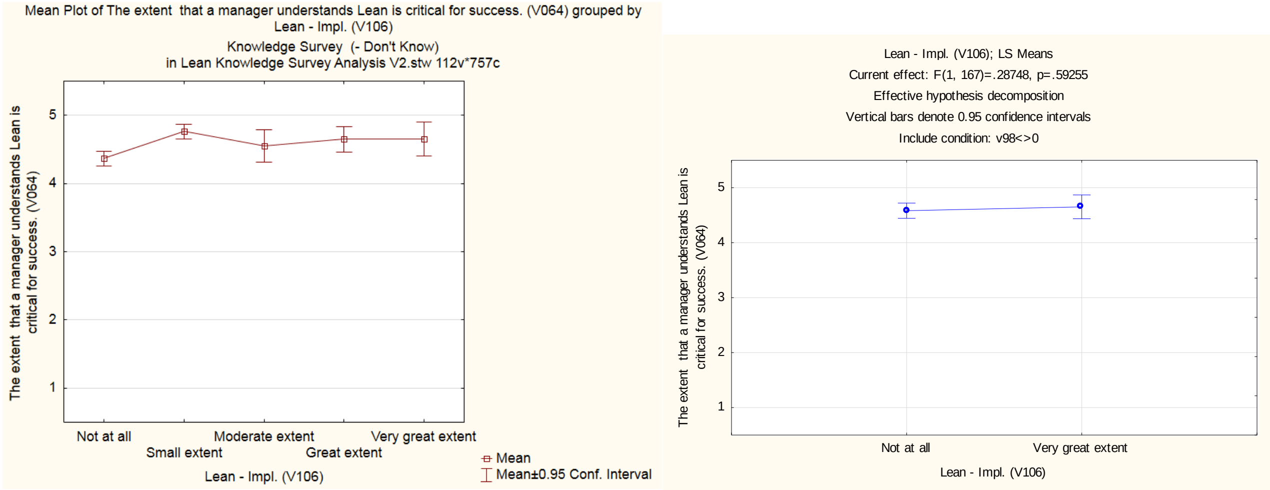


Figure 260 "The extent that management understands lean is critical for success" (1= Disagree, 5 = Strongly agree).

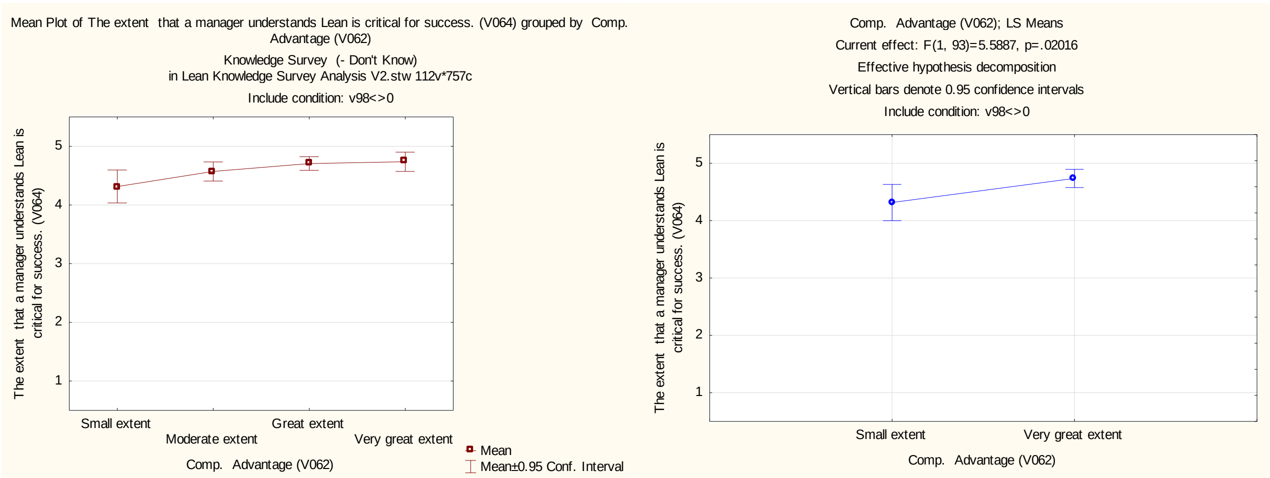


Figure 261 "The extent that management understands lean is critical for success" ANOVA by competitive advantage of lean (1= Disagree, 5 = Strongly agree).

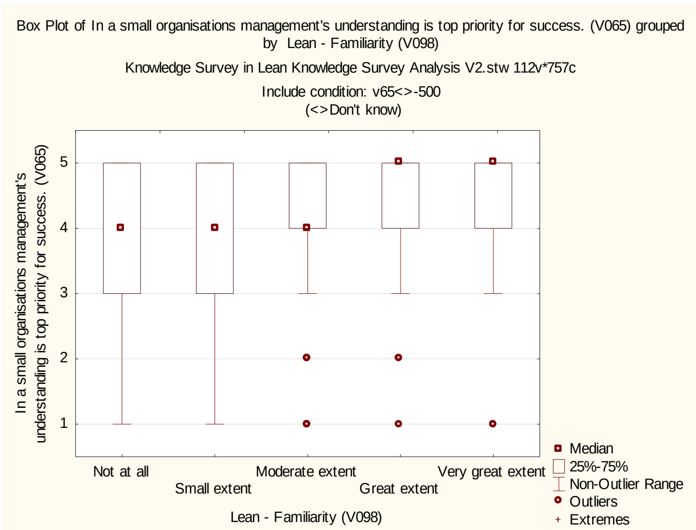


Figure 262 "In a small organisation managements' understanding of lean is top priority for success" box plot by familiarity with lean (1= Disagree, 5 = Strongly agree).

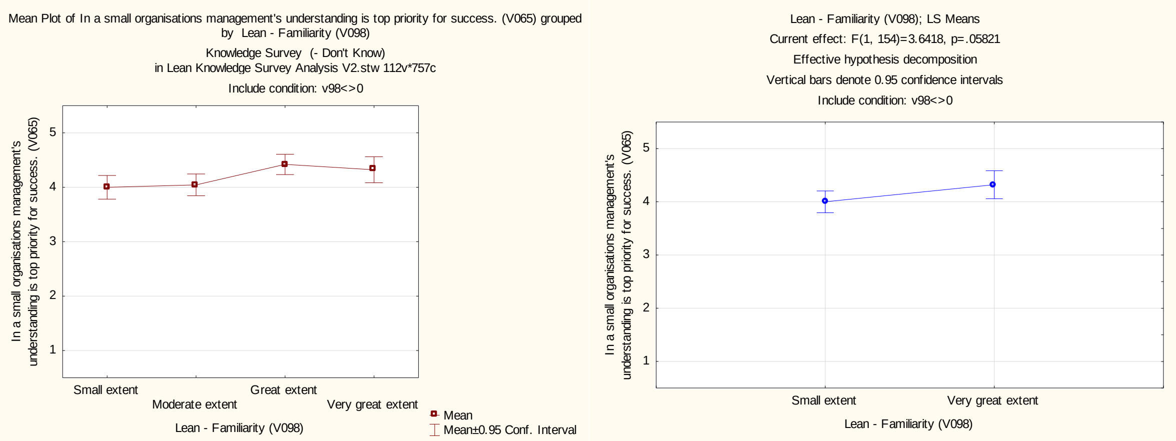


Figure 263 "In a small organisation managements' understanding of lean is top priority for success" ANOVA by familiarity with lean (1= Disagree, 5 = Strongly agree).

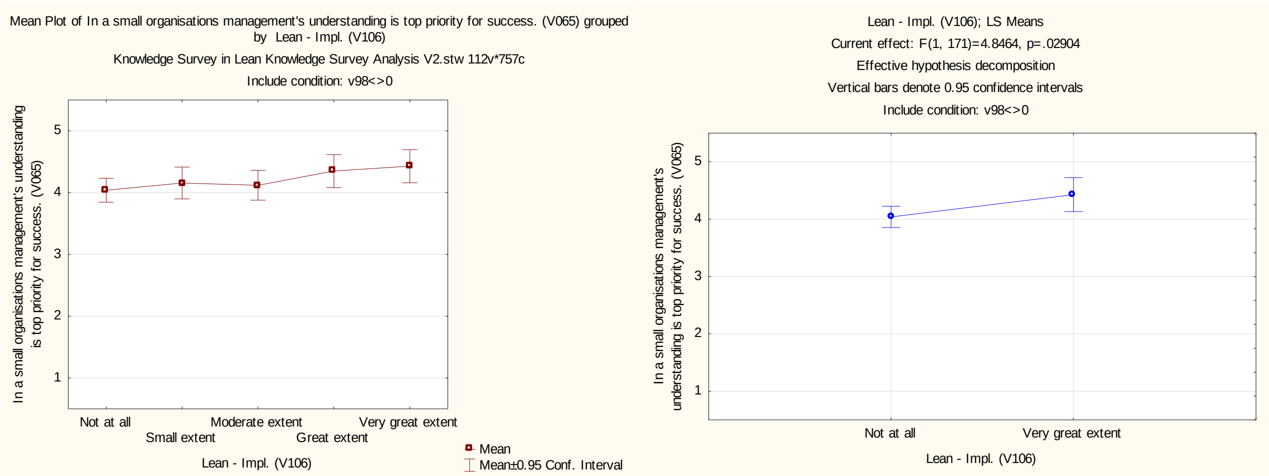


Figure 264 "In a small organisation managements' understanding of lean is top priority for success" (1= Disagree, 5 = Strongly agree).

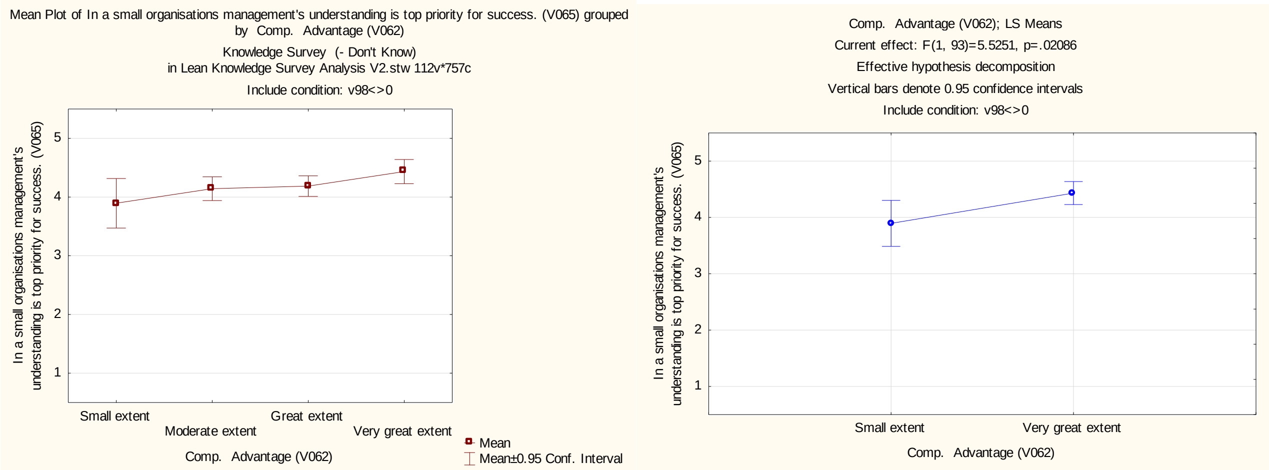


Figure 265 "In a small organisation managements' understanding of lean is top priority for success" ANOVA by Competitive Advantage of lean (1= Disagree, 5 = Strongly agree).

13.1.9 Key Variable Scatter Plots

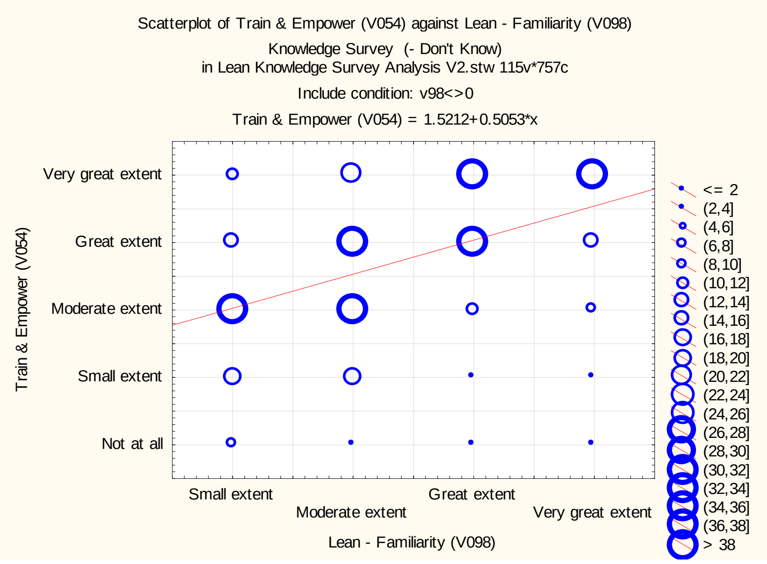


Figure 266 Lean is Training and Empowerment by Familiarity (scatter plot).

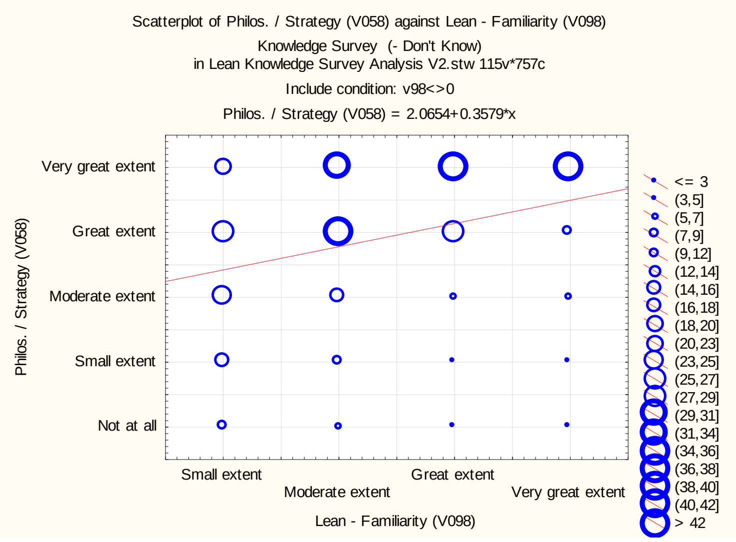


Figure 267 Lean is Philosophy and Strategy by Familiarity (scatter plot).

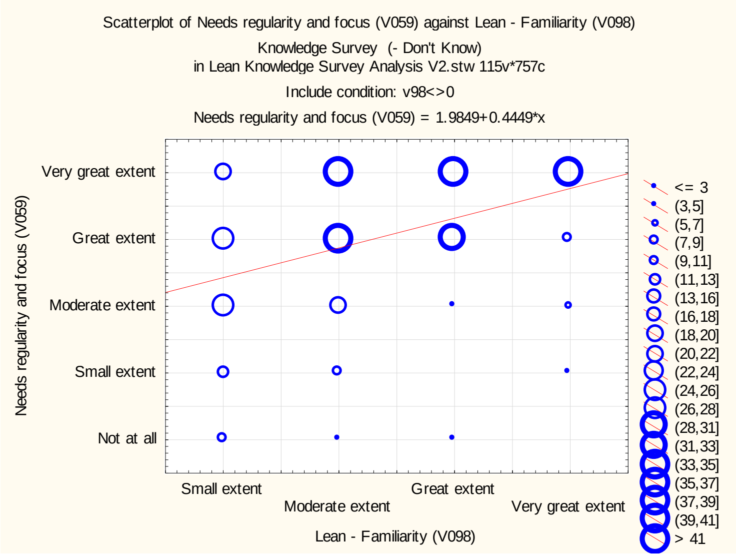


Figure 268 Lean Needs Regularity and Focus by Familiarity (scatter plot).

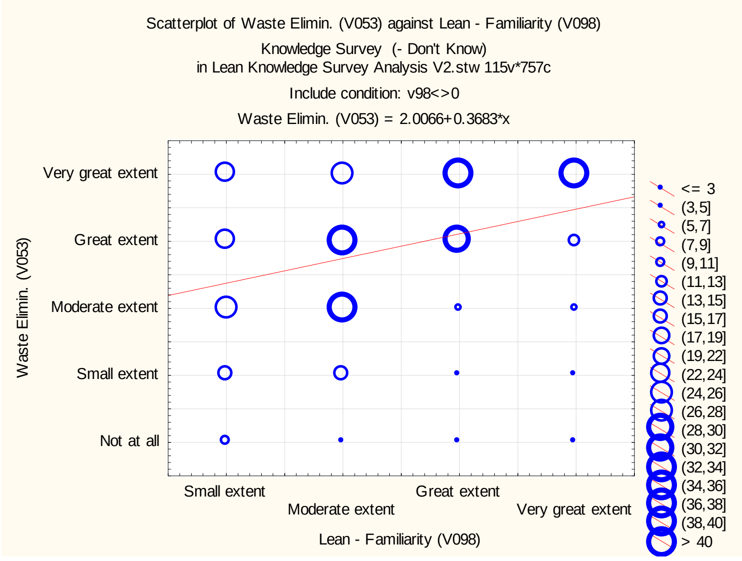


Figure 269 Lean is Waste Elimination by Familiarity (scatter plot).

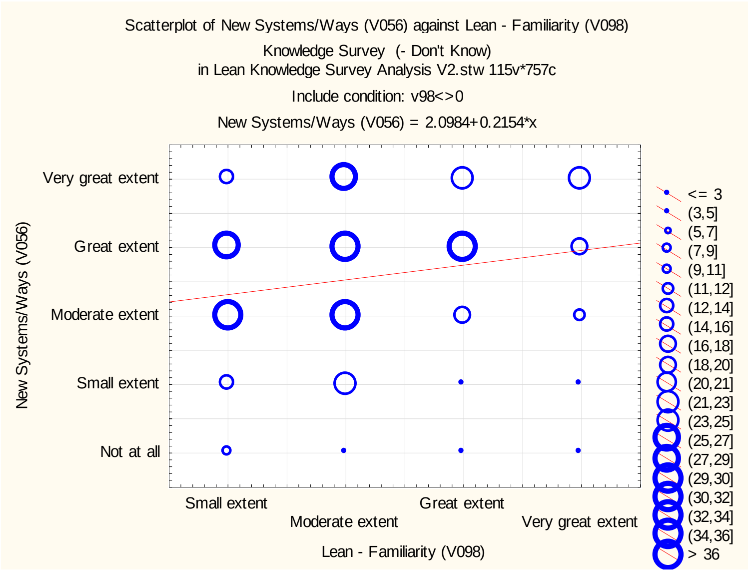


Figure 270 Lean is New Systems and Ways by Familiarity (scatter plot).

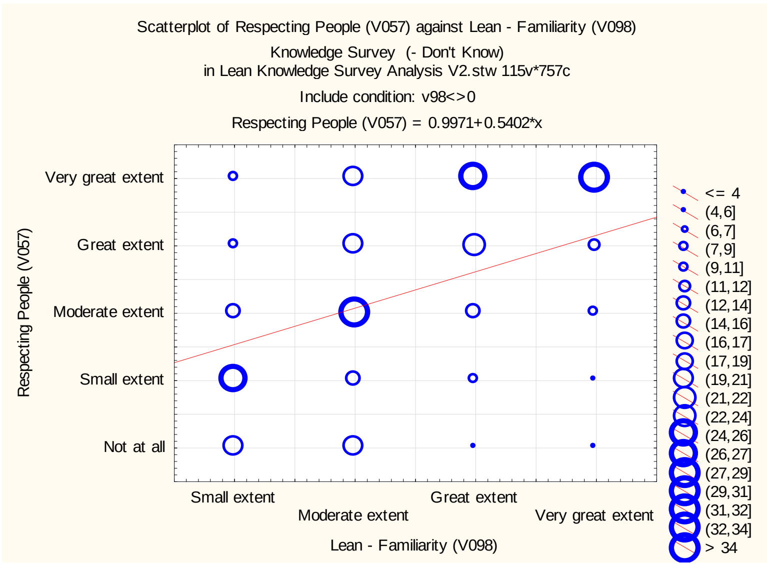


Figure 271 Lean is Respecting People by Familiarity (scatter plot).

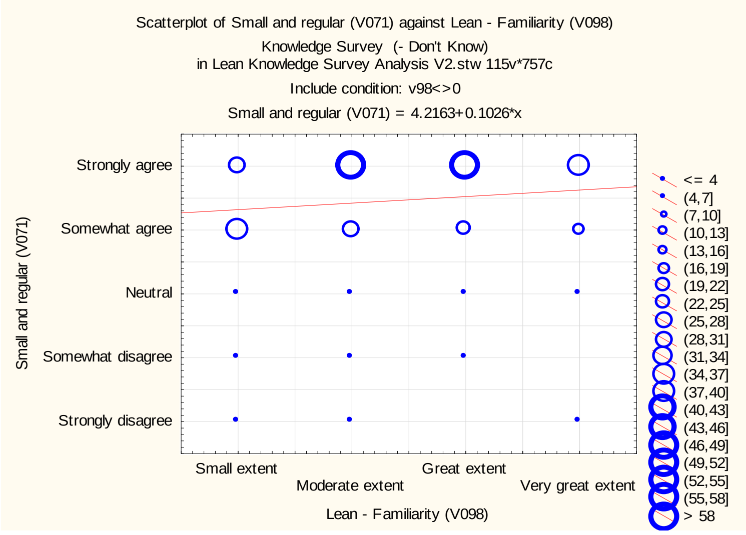


Figure 272 Small and Regular for Lean by Familiarity (scatter plot).

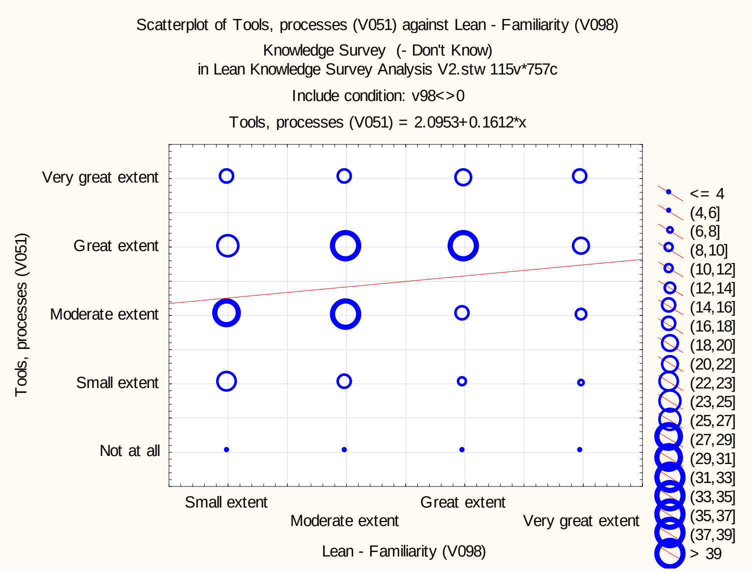


Figure 273 Lean is Tools and Processes by Familiarity (scatter plot).

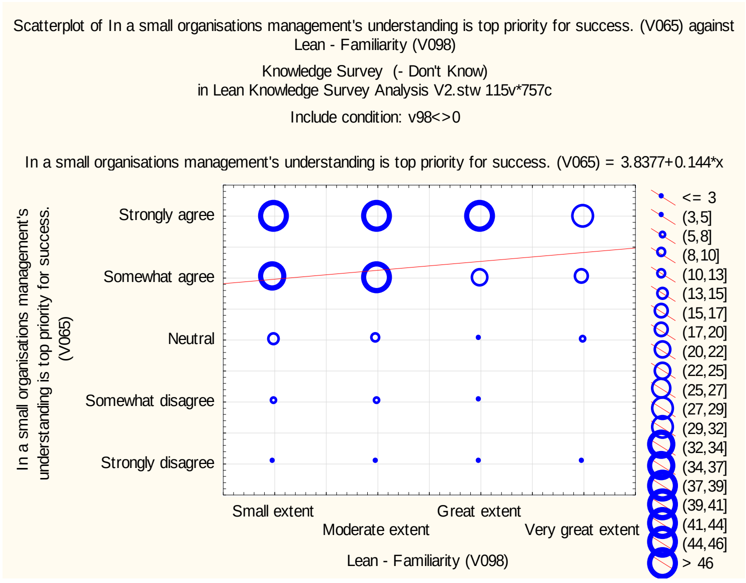
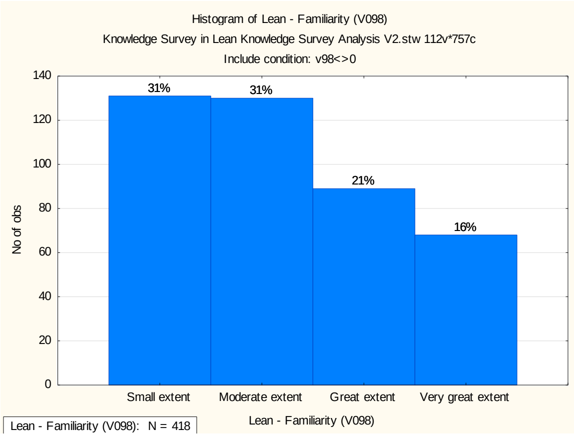


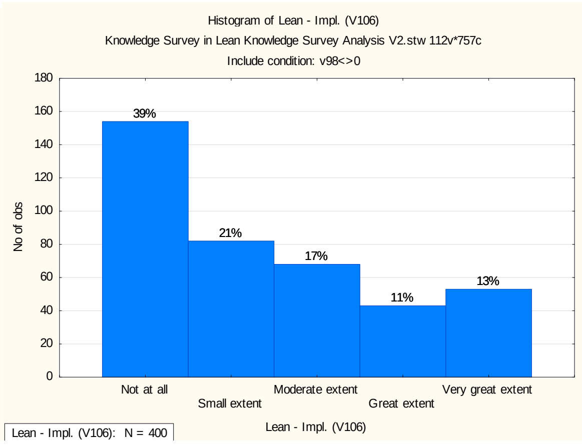
Figure 274 In a small organisation... management understanding by Familiarity (scatter plot).

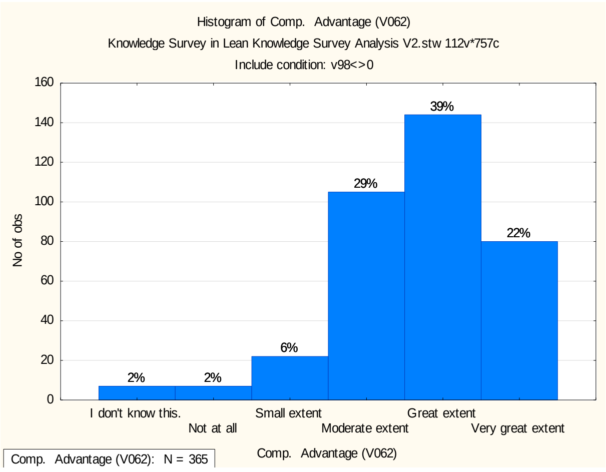
13.1.10 Variable Screening

These figures were produced for the purpose of variable screening only and hence are not labelled individually as figures for this document. All though skew is present, the data was deemed suitable; see results analysis sections for more details

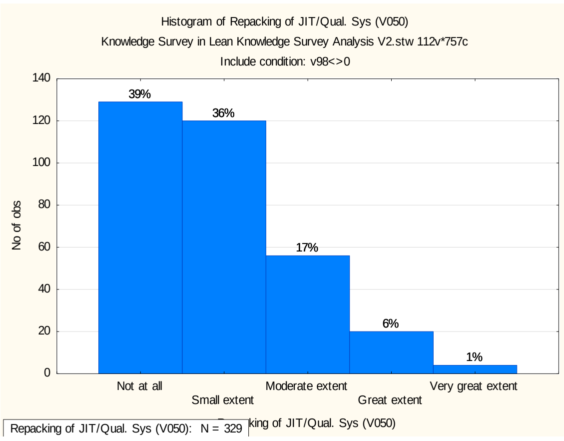
Grouping Variables

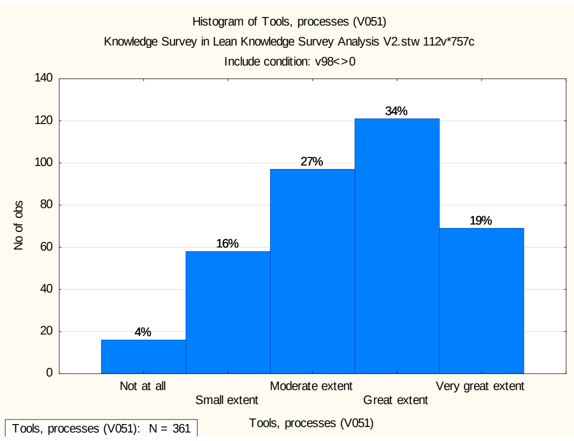


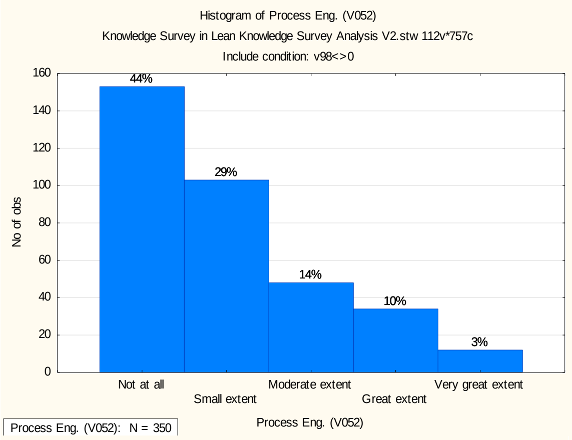


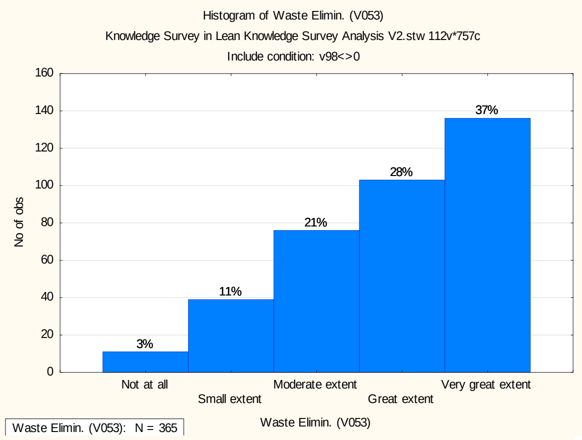


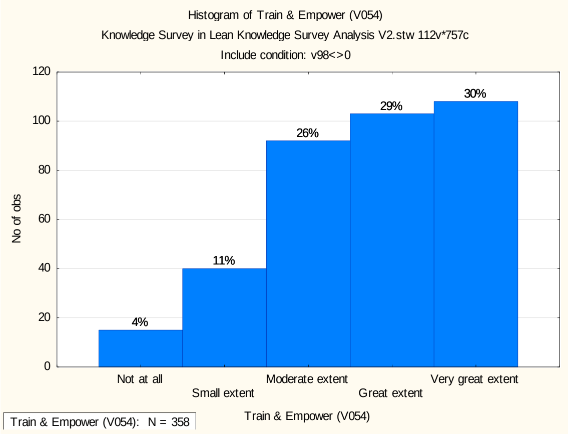
Lean Understanding Questions

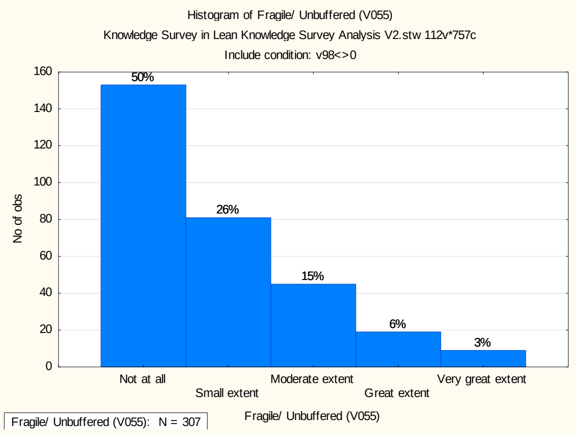


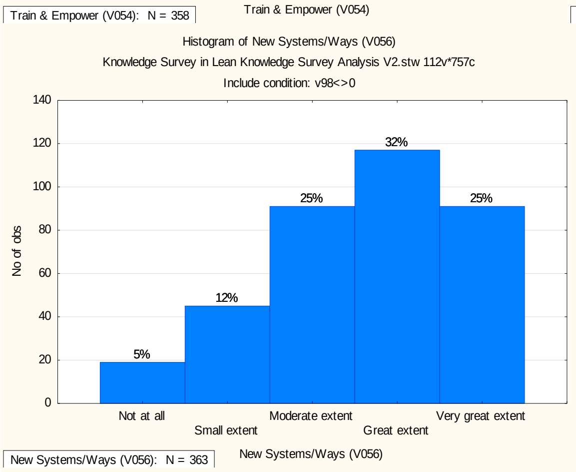


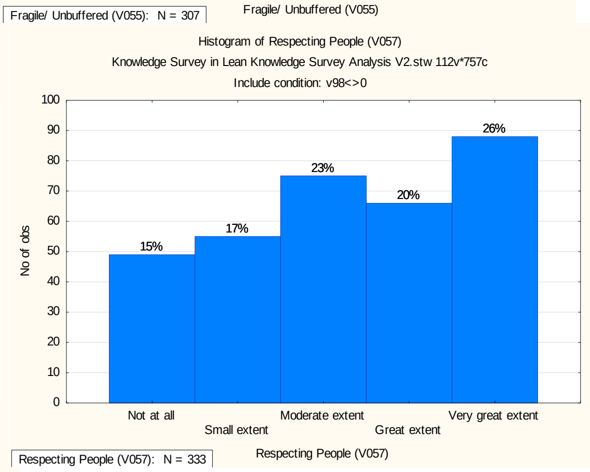

Histogram of Process Eng. (V052)
Knowledge Survey in Lean Knowledge Survey Analysis V2.stw 112v*757c
Include condition: v98<>0
No of obs
0
20
40
60
80
100
120
140
160
44%
29%
14%
10%
3%
Not at all
Small extent
Moderate extent
Great extent
Very great extent
Process Eng. (V052): N = 350
Process Eng. (V052)

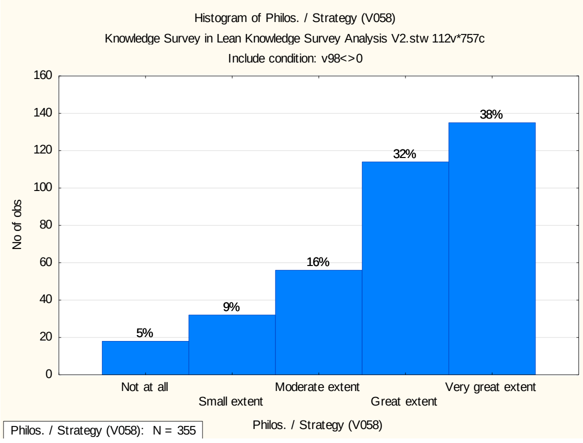

Histogram of Waste Elimin. (V053)
Knowledge Survey in Lean Knowledge Survey Analysis V2.stw 112v*757c
Include condition: v98<>0
No of obs
0
20
40
60
80
100
120
140
160
3%
11%
21%
28%
37%
Not at all
Small extent
Moderate extent
Great extent
Very great extent
Waste Elimin. (V053): N = 365
Waste Elimin. (V053)

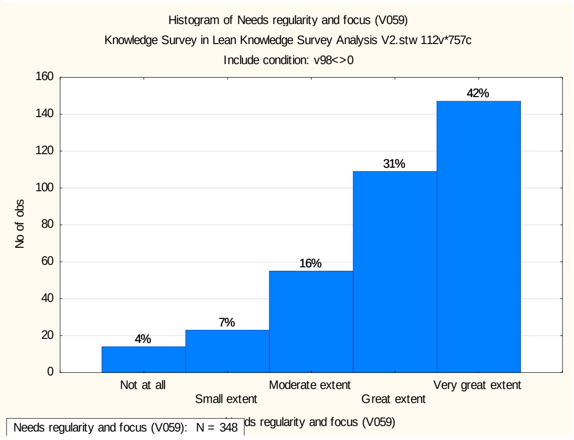

Histogram of Train & Empower (V054)
Knowledge Survey in Lean Knowledge Survey Analysis V2.stw 112v*757c
Include condition: v98<>0
No of obs
0
20
40
60
80
100
120
4%
11%
26%
29%
30%
Not at all
Small extent
Moderate extent
Great extent
Very great extent
Train & Empower (V054): N = 358
Train & Empower (V054)

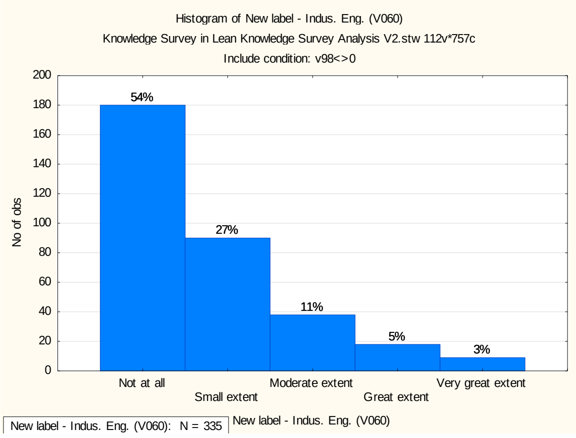

Histogram of Fragile/ Unbuffered (V055)
Knowledge Survey in Lean Knowledge Survey Analysis V2.stw 112v*757c
Include condition: v98<>0
No of obs
0
20
40
60
80
100
120
140
160
50%
26%
15%
6%
3%
Not at all
Small extent
Moderate extent
Great extent
Very great extent
Fragile/ Unbuffered (V055): N = 307
Fragile/ Unbuffered (V055)


Histogram of New Systems/Ways (V056)
Knowledge Survey in Lean Knowledge Survey Analysis V2.stw 112v*757c
Include condition: v98<>0
No of obs
0
20
40
60
80
100
120
140
5%
12%
25%
32%
25%
Not at all
Small extent
Moderate extent
Great extent
Very great extent
New Systems/Ways (V056): N = 363
New Systems/Ways (V056)

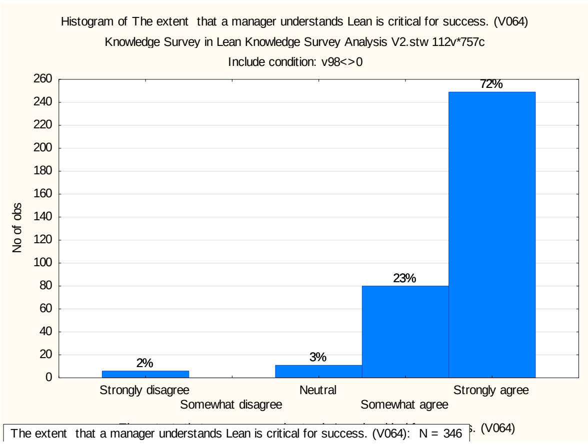

Histogram of Respecting People (V057)
Knowledge Survey in Lean Knowledge Survey Analysis V2.stw 112v*757c
Include condition: v98<>0
No of obs
0
10
20
30
40
50
60
70
80
90
100
15%
17%
23%
20%
26%
Not at all
Small extent
Moderate extent
Great extent
Very great extent
Respecting People (V057): N = 333
Respecting People (V057)


Histogram of Philos. / Strategy (V058)
Knowledge Survey in Lean Knowledge Survey Analysis V2.stw 112v*757c
Include condition: v98<>0
No of obs
0
20
40
60
80
100
120
140
160
5%
9%
16%
32%
38%
Not at all
Small extent
Moderate extent
Great extent
Very great extent
Philos. / Strategy (V058): N = 355
Philos. / Strategy (V058)

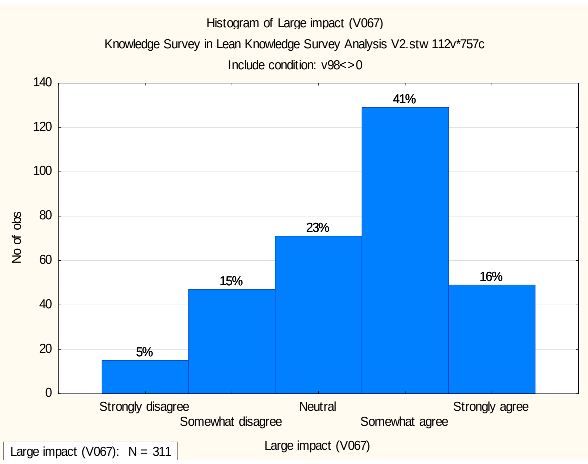

Histogram of Needs regularity and focus (V059)
Knowledge Survey in Lean Knowledge Survey Analysis V2.stw 112v*757c
Include condition: v98<>0
No of obs
0
20
40
60
80
100
120
140
160
4%
7%
16%
31%
42%
Not at all
Small extent
Moderate extent
Great extent
Very great extent
Needs regularity and focus (V059): N = 348
ds regularity and focus (V059)

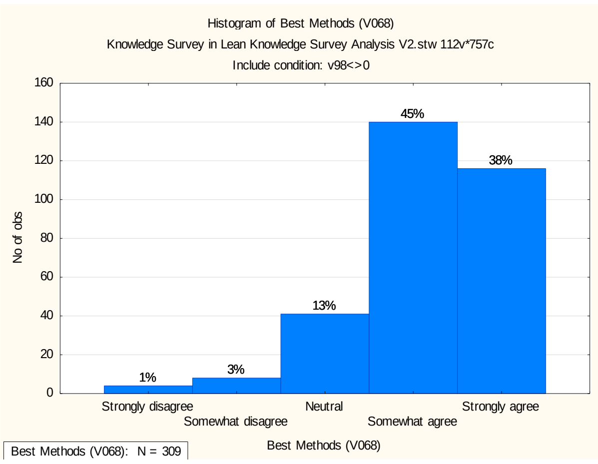


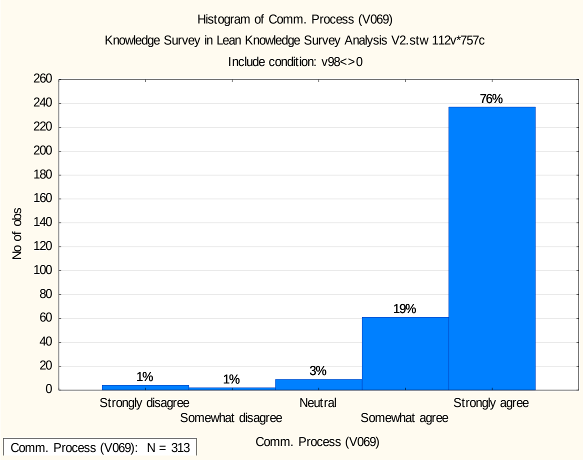
Managements’ Understanding Questions

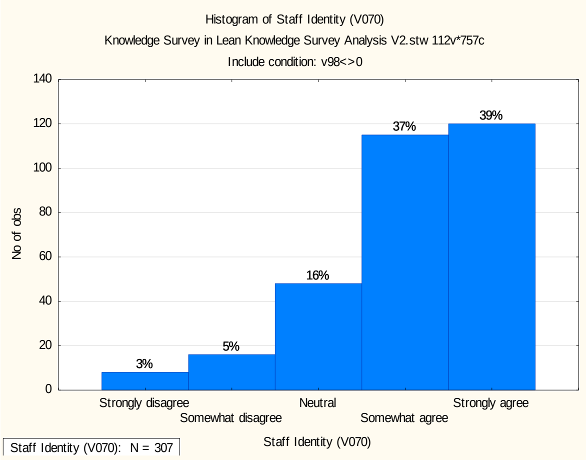


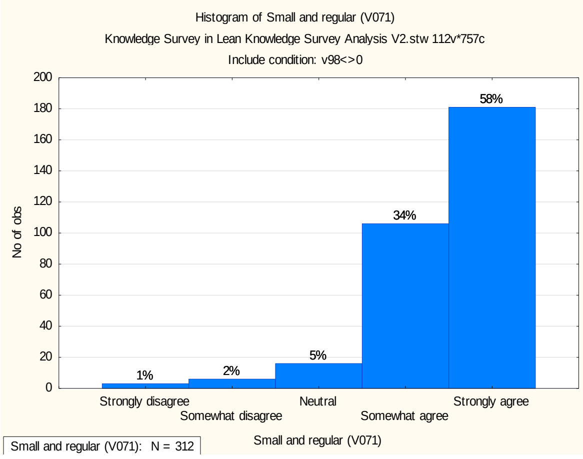
Lean Implementation Questions

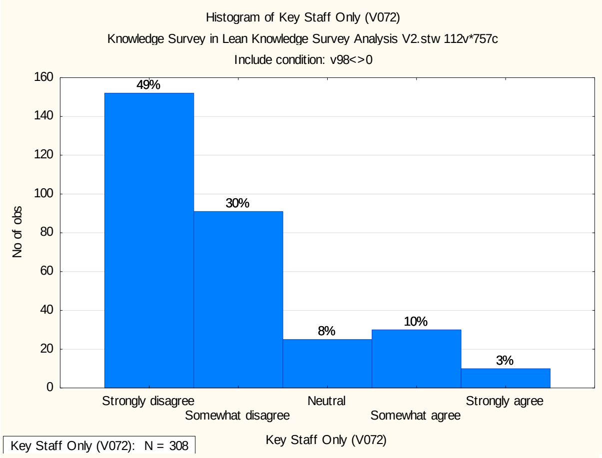


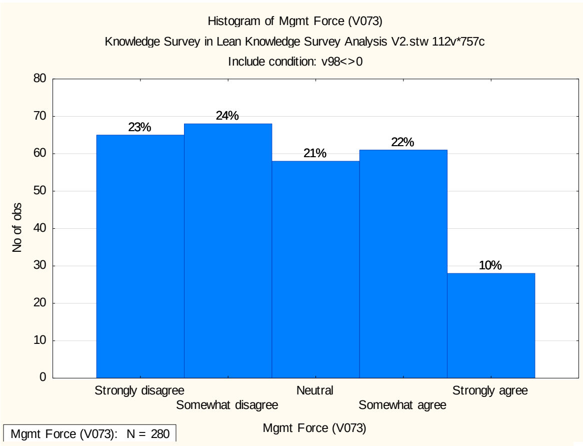


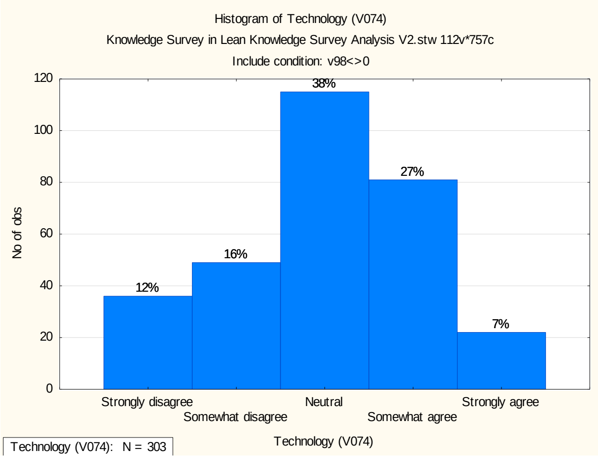

Histogram of Comm. Process (V069)
Knowledge Survey in Lean Knowledge Survey Analysis V2.stw 112v*757c
Include condition: v98<>0
No of obs
0 20 40 60 80 100 120 140 160 180 200 220 240 260
1% 1% 3% 19% 76%
Strongly disagree
Somewhat disagree
Neutral
Somewhat agree
Strongly agree
Comm. Process (V069): N = 313
Comm. Process (V069)

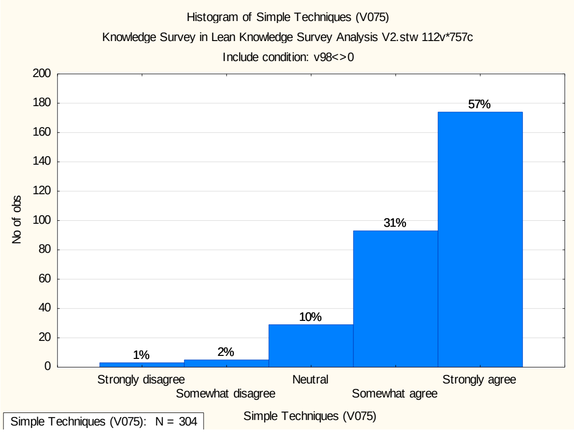

Histogram of Staff Identity (V070)
Knowledge Survey in Lean Knowledge Survey Analysis V2.stw 112v*757c
Include condition: v98<>0
No of obs
0 20 40 60 80 100 120 140
3% 5% 16% 37% 39%
Strongly disagree
Somewhat disagree
Neutral
Somewhat agree
Strongly agree
Staff Identity (V070): N = 307
Staff Identity (V070)


Histogram of Small and regular (V071)
Knowledge Survey in Lean Knowledge Survey Analysis V2.stw 112v*757c
Include condition: v98<>0
No of obs
0 20 40 60 80 100 120 140 160 180 200
1% 2% 5% 34% 58%
Strongly disagree
Somewhat disagree
Neutral
Somewhat agree
Strongly agree
Small and regular (V071): N = 312
Small and regular (V071)


Histogram of Key Staff Only (V072)
Knowledge Survey in Lean Knowledge Survey Analysis V2.stw 112v*757c
Include condition: v98<>0
No of obs
0 20 40 60 80 100 120 140 160
49% 30% 8% 10% 3%
Strongly disagree
Somewhat disagree
Neutral
Somewhat agree
Strongly agree
Key Staff Only (V072): N = 308
Key Staff Only (V072)


Histogram of Mgmt Force (V073)
Knowledge Survey in Lean Knowledge Survey Analysis V2.stw 112v*757c
Include condition: v98<>0
No of obs
0 10 20 30 40 50 60 70 80
23% 24% 21% 22% 10%
Strongly disagree
Somewhat disagree
Neutral
Somewhat agree
Strongly agree
Mgmt Force (V073): N = 280
Mgmt Force (V073)


Histogram of Technology (V074)
Knowledge Survey in Lean Knowledge Survey Analysis V2.stw 112v*757c
Include condition: v98<>0
No of obs
0 20 40 60 80 100 120
12% 16% 38% 27% 7%
Strongly disagree
Somewhat disagree
Neutral
Somewhat agree
Strongly agree
Technology (V074): N = 303
Technology (V074)


Histogram of Simple Techniques (V075)
Knowledge Survey in Lean Knowledge Survey Analysis V2.stw 112v*757c
Include condition: v98<>0
No of obs
0 20 40 60 80 100 120 140 160 180 200
1% 2% 10% 31% 57%
Strongly disagree
Somewhat disagree
Neutral
Somewhat agree
Strongly agree
Simple Techniques (V075): N = 304
Simple Techniques (V075)

13.2 Experiment Two

13.2.1 Second Tier Outcomes

Consultant Capability by Outcomes and Country

Figure 275, Figure 276, and Figure 277 are plots of key success variables versus consultant capability. As per correlations indicated, there is no significant difference between the presence of a good capable or even masterful consultant and lean success. Smaller charts showing full range of extents are included for reference and can be viewed easily in the in electronic form.

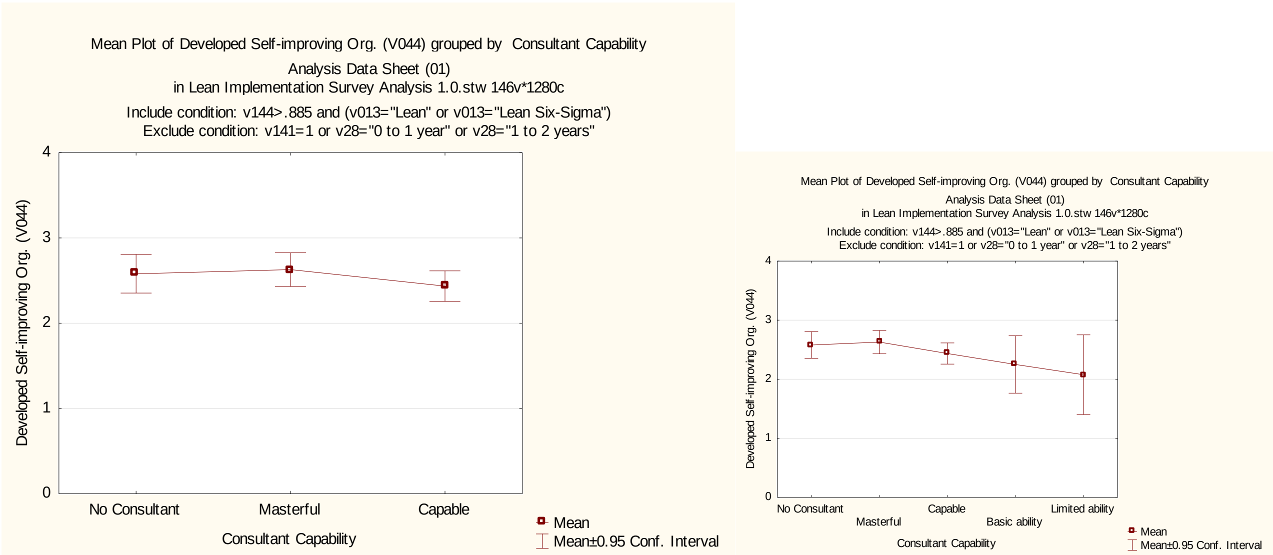


Figure 275 Means plot for Developed Self-improving Org. by Consultant Capability (scale 0- 4 is not at all, small extent, great extent, and very great extent, 95% CI).

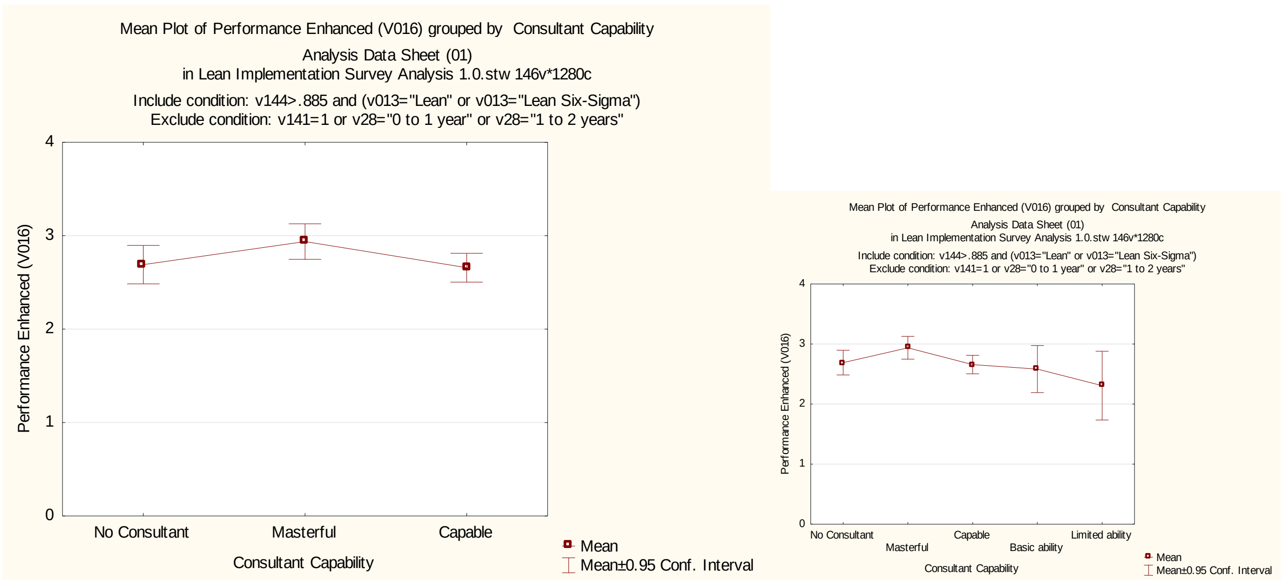


Figure 276 Means plot for Performance Enhanced by Consultant Capability (scale 0- 4 is not at all, small extent, great extent, and very great extent, 95% CI).

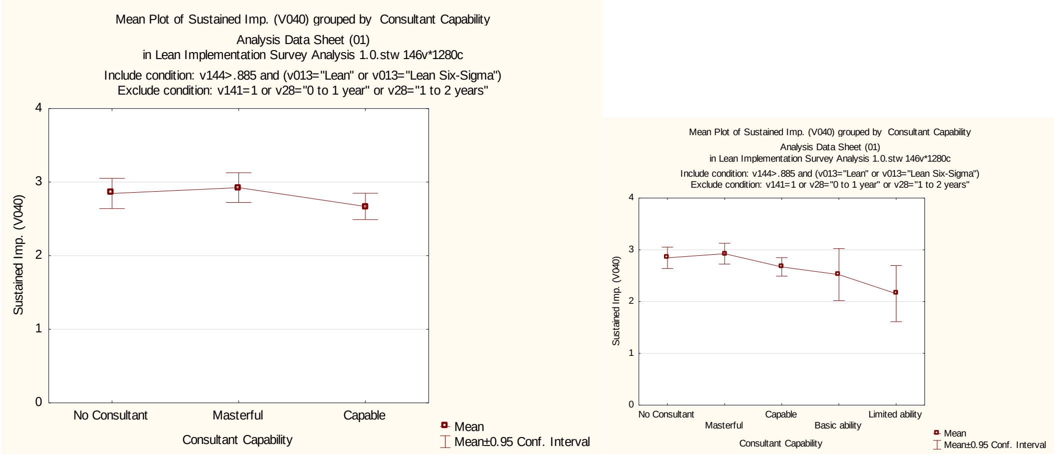
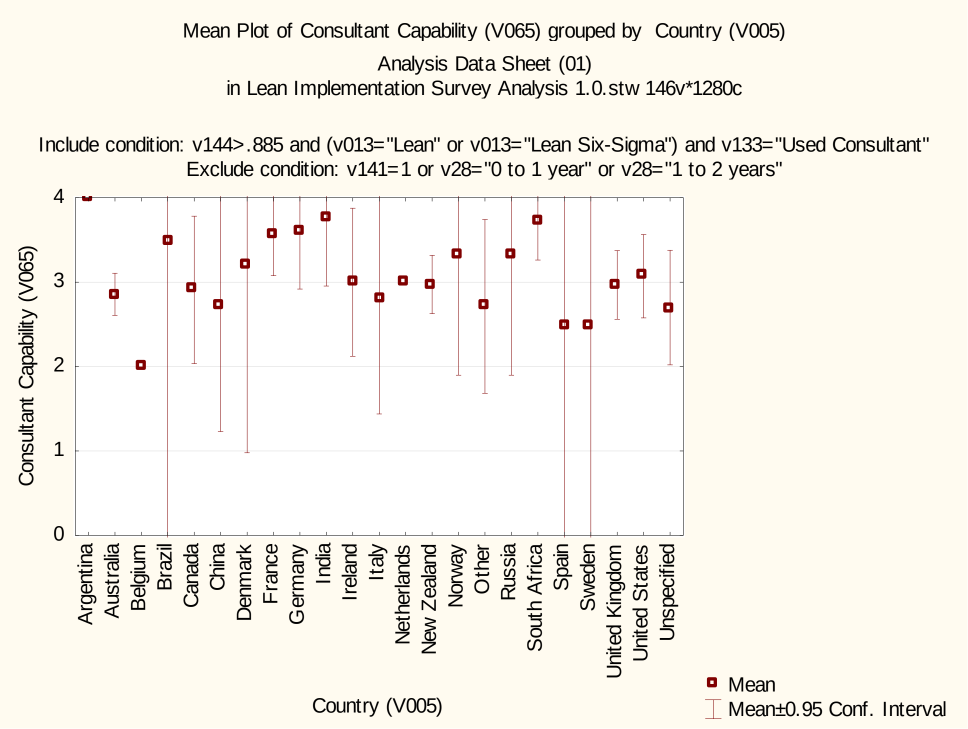


Figure 277 Means plot for Sustained Implementation by Consultant Capability (scale 0- 4 is not at all, small extent, great extent, and very great extent, 95% CI).

Figure 278 shows the means plot for consultant capability by country. Confidence interval whiskers (95%) show some of the countries did not have significant data in this category for comparison. Looking at those of narrower confidence interval shows means capabilities are reported from 3 (capable) up towards 4 (masterful). France, Germany, India and South Africa are seen to have a generally higher consultant capability compared to New Zealand, Australia, the United Kingdom, and the United States whom all have very similar consultant capabilities (i.e. mean value = 3, “capable”). However the later are represented by many more cases (~30 each while the former 7 or less each) reducing accuracy of the mean. Positivity bias (if present) could also be more evident at the smaller number of responses. Additionally the differences between means appear to be borderline significant between means. With that disclaimer added, however indications are that Western Europe (continental) has a higher calibre of consultants operating than other parts of the world.



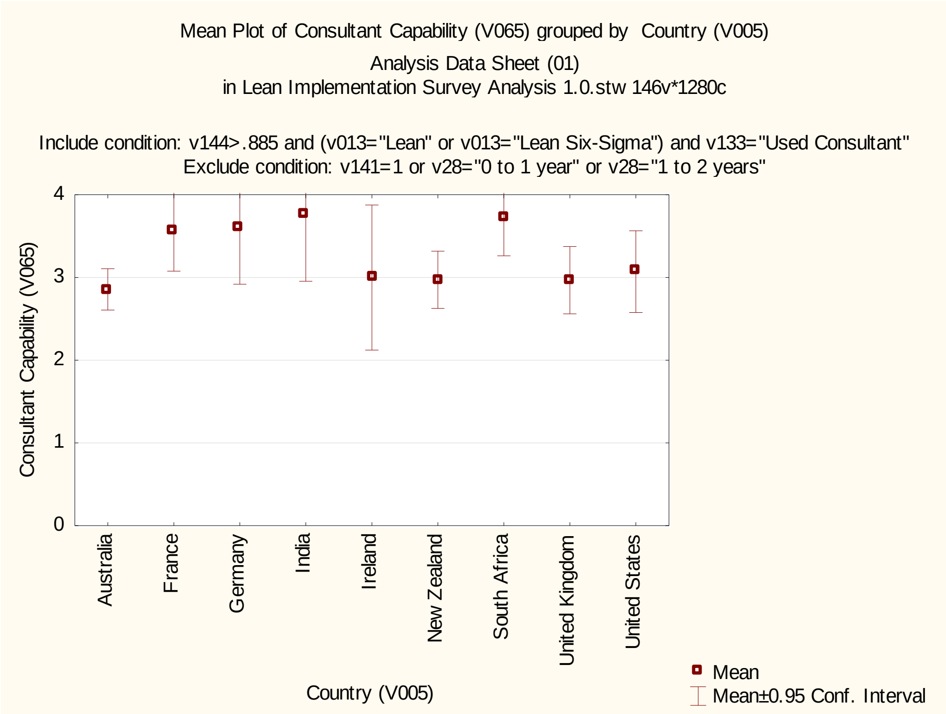


Figure 278 Means plot for consultant capability by country – all comparison (above) and smaller confidence band (below) (scale 0- 4 is None/not at all, limited ability, basic ability, capable and masterful, 95% CI).

No differences were seen between Lean and Lean Six-sigma for consultant variables. Capability, use in general, use in implementation, and use in coaching showed no significant difference between means.

Resource Indicator Relationships in Knowledge-Based View

In the high-variety low volume Lean Knowledge-Based View, resource capability was removed (p. 278). The below summarises correlations observed.

As a single indicator construct Staff Capability showed the following negative relationships JIT->Staff Capability β=-0.29, and Information Systems -> Staff Capability β=-0.30. Other relationships include: Management Knowledge -> Staff Capability β=0.27 directly but with the following mediation added it dropped to insignificant and β=0.02. The mediation was through Planning -> Staff Capability β=0.17; Communication -> Staff Capability β=0.23; and Regularity -> Staff Capability β=0.35. These described Staff Capability to R^2 =0.47. Overall, the effect did not describe outcomes more and as a spurious measure with uncertain causality, it was removed.

Technology Capability was a single indicator construct. Investigations showed the following relationships: Management Knowledge -> Technology Capability β=0.48, Planning -> Technology Capability β=-0.55, Communication -> Technology Capability β=0.32 (indicating communication of the change), Guiding Coalition -> Technology Capability β=0.44, Statistical Methods -> Technology Capability β=0.26, Pull/Kanban -> Technology Capability β=-0.30, and Support Employees -> Technology Capability β=-0.16. It did not show a direct relationship with Information Systems.

No problems with discriminant validity or other quality measures were observed.

Full Variable Ranking

The ranking of all variables against Implementation Success (V162) was conducted by a Chi-square regression algorithm using pair-wise deletion.

	Chi-square	p-value
Mgmt. continued to learn and participate (V105)	87.2	0.000000
Staff had KPIs/clear goals (V104)	78.8	0.000000
Worker Initiatives (V041)	76.0	0.000000
Mgmt. - Comm. Staff Role (Alignment) (V052)	75.2	0.000000
Visual Systems (V098)	72.5	0.000000
Management Commit. (V036)	71.2	0.000000
Involved all Staff (V057)	70.3	0.000000
Mgmt. - Effective Comm. Process (V050)	70.0	0.000000
Growth mindset (can learn/improve) (V075)	66.8	0.000000
Easy for suggestion/improvements. (V048)	66.6	0.000000
Culture Initial priority (V049)	64.8	0.000000
Mgmt. - Vivid Comm. Strategy/Vis] (V051)	62.6	0.000000
Standard work developed (V080)	59.2	0.000000
Mgmt. understood as a new culture/philosophy (V068)	59.0	0.000000
Mgmt. - Vivid Comm. Steps of Change (V053)	58.8	0.000000
Easy to maintain momentum (V070)	57.1	0.000000
Momentum Constant (V032)	54.9	0.000000
Mgmt understood tools/methods (V067)	54.3	0.000000
Pull Systems (V094)	54.2	0.000000
Program/Structure/Regularity (V078)	53.7	0.000000

Staff Trusted Mgmt. (V056)	52.6	0.000000
Mgmt. Planned Well (V047)	51.1	0.000000
Mgmt. had excellent lean knowledge (V055)	50.1	0.000000
Mgmt. established lean knowledge at start (V106)	50.0	0.000000
Management Capability (V064)	48.8	0.000000
Impl. Leader Capability (V066)	48.6	0.000000
Root Cause Analysis (V099)	46.5	0.000000
Staff in Planning. (V039)	46.5	0.000000
New staff identity devel. (V074)	44.9	0.000000
Kanban (V095)	44.4	0.000000
Individual support in adjusting (V079)	44.1	0.000000
Mgmt. commit. training (V054)	43.2	0.000000
Engaging suppliers (V100)	42.3	0.000000
Guiding coalition supporting. (V077)	40.1	0.000000
Defining Value (V093)	39.5	0.000000
Simple problem solving. (V092)	39.3	0.000000
New Culture Emphasis (V037)	37.0	0.000000
Just In Time Manufacture (V087)	35.8	0.000000
Lean/flow accounting (V058)	35.7	0.000000
Journey View (V031)	34.3	0.000001
Engaging customers (V101)	33.7	0.000001
Flow focus (vs utilisation) (V059)	33.6	0.000001
Total Productive Maintenance (V089)	33.5	0.000001
5 Whys (V091)	31.8	0.000002
Staff Capability (V062)	31.1	0.000003
Country (V005)	30.7	0.102629
Used Incentives (V042)	28.2	0.000011
Mapping Value Stream (V097)	27.6	0.000015
Staff warned of the struggle (V076)	26.9	0.000021
Emphasis Proc. Imprv. (V034)	23.9	0.000085
Small wins prominent (V072)	22.7	0.000146
Statistical Methods (V096)	21.2	0.000284
5S System (V086)	20.7	0.000358
Kaizen (Kaikaku) Improvement Events (V090)	20.3	0.000443
Technology Capability (V063)	20.1	0.000480
Org. Flatness (V029)	18.3	0.001098
Groups of Positive Staff (V069)	17.6	0.001452
Impl. review and planning (V083)	16.1	0.006607
Org. Classification (V025)	15.0	0.036255
Management Press still Needed (V061)	14.0	0.007382
Role (V019)	12.8	0.076213
Implementation Run time (V028)	12.2	0.016087
PCMH (Previous bad experiences) (V084)	12.1	0.016315
Performance review/support (V082)	11.4	0.044547
Culture similar or conducive already exists.] (V103)	11.1	0.011005
Started Well (V033)	10.7	0.030148
Consultant Capability (V065)	10.2	0.036453
A3 Management, or Nemawashi or Catchball process (V088)	10.1	0.039163
Was Leader (V021)	9.8	0.044484
Sample Group (V003)	8.5	0.132264
Employees resisted change (V102)	8.2	0.083794

Industry (V023)	6.1	0.805300
Information Systems (V085)	5.6	0.228077
Mgmt. Pressure was needed (V060)	4.9	0.301365
Employees Categorical (V163)	4.6	0.601336
Financial Situation (V045)	4.5	0.342388
Consultants as a coach. (V073)	3.7	0.454202
Work experience (V007)	3.3	0.652295
Case Method (V013)	3.1	0.077273
Fear as a Motivator (V071)	3.0	0.393662
Staff meetings. (V081)	3.0	0.703745
Implementation by consultants (V035)	2.9	0.582871
Driven by External Support (V043)	2.8	0.419378
Staff No. (V027)	2.5	0.637530
Consultant Use (V133)	0.3	0.584334

Figure 279 Variable Ranking for Implementation Success (V162) by Chi-square regression algorithms (pair-wise deletion). Marked correlations are not significant to p<0.05.

13.2.2 Additional Results Data and Plots

Correlation Matrix Input vs Output

Correlations (Analysis Data Sheet (01) in Lean Implementation Survey Analysis 0.2.stw). Marked correlations are significant at p < .02000. Include condition: v144>.885 and (v013="Lean" or v013="Lean Six-Sigma"). Exclude condition: v141=1 or v28="0 to 1 year" or v28="1 to 2 years"

	Competitive Advantage (V015)	Performance Enhanced (V016)	Staff Morale Increased (V017)	New Culture Developed (V038)	Sustained Implementation (V040)	Developed Self-improving Org. (V044)	Management Pressure still Needed (V061)	New staff identity developed (V074)	Employees resisted change (V102)
Implemented Lean or TPS (V008)	.3900 N=389 p=.000	.2840 N=391 p=.000	.2454 N=390 p=.000	.3005 N=389 p=.000	.2546 N=379 p=.000	.2645 N=390 p=.000	-.0259 N=372 p=.619	.1293 N=385 p=.011	.0889 N=392 p=.079
Implemented Theory of Constraints (V009)	.2052 N=357 p=.000	.2330 N=359 p=.000	.1584 N=358 p=.003	.1491 N=357 p=.005	.1310 N=348 p=.014	.1727 N=358 p=.001	-.0070 N=341 p=.897	.1087 N=353 p=.041	.0565 N=360 p=.285
Implemented Agile (Mfg.) (V010)	.3339 N=331 p=.000	.2928 N=332 p=.000	.1730 N=332 p=.002	.2656 N=330 p=.000	.1648 N=323 p=.003	.2626 N=332 p=.000	-.0153 N=315 p=.787	.1529 N=326 p=.006	.0269 N=333 p=.625
Implemented Agile (IT) (V011)	.2555 N=326 p=.000	.2321 N=327 p=.000	.1750 N=326 p=.002	.2199 N=325 p=.000	.1846 N=317 p=.001	.2333 N=327 p=.000	-.0975 N=311 p=.086	.1465 N=321 p=.009	.0055 N=328 p=.921
Implemented Quality Systems (V012)	.2612 N=377 p=.000	.2667 N=378 p=.000	.1864 N=378 p=.000	.3003 N=378 p=.000	.1842 N=367 p=.000	.3123 N=378 p=.000	.0145 N=361 p=.783	.2650 N=373 p=.000	.0289 N=380 p=.575
The above variables are the self-reported experience of the survey participants; they are not necessarily related to the implementation. Implementation variables are below.									
Staff No. (V027)	.0346 N=383 p=.499	.0174 N=384 p=.734	.0354 N=384 p=.489	.0138 N=383 p=.788	.0085 N=373 p=.870	.0414 N=384 p=.419	.0657 N=366 p=.210	.0827 N=379 p=.108	.1717 N=386 p=.001
Was Leader (V021)	.2595 N=384	.2874 N=385	.2440 N=385	.2486 N=384	.1810 N=374	.2317 N=385	-.0494 N=367	.0782 N=380	-.0559 N=387

	Competitive Advantage (V015)	Performance Enhanced (V016)	Staff Morale Increased (V017)	New Culture Developed (V038)	Sustained Implementation (V040)	Developed Self-improving Org. (V044)	Management Pressure still Needed (V061)	New staff identity developed (V074)	Employees resisted change (V102)
	p=.000	p=.000	p=.000	p=.000	p=.000	p=.000	p=.345	p=.128	p=.272
Org. Flatness (V029)	.1692 N=389 p=.001	.1961 N=390 p=.000	.1297 N=390 p=.010	.2263 N=389 p=.000	.1867 N=379 p=.000	.2048 N=390 p=.000	-.1350 N=372 p=.009	.0792 N=385 p=.121	-.0877 N=392 p=.083
Journey View (V031)	.3530 N=389 p=.000	.3045 N=390 p=.000	.2804 N=390 p=.000	.5114 N=389 p=0.00	.3936 N=379 p=.000	.4084 N=390 p=.000	-.1442 N=372 p=.005	.2011 N=385 p=.000	-.0101 N=392 p=.842
Momentum Constant (V032)	.3408 N=390 p=.000	.3403 N=391 p=.000	.2664 N=391 p=.000	.3889 N=390 p=.000	.5022 N=380 p=0.00	.4672 N=391 p=0.00	-.1755 N=373 p=.001	.1892 N=386 p=.000	-.1120 N=393 p=.026
Started Well (V033)	.1520 N=388 p=.003	.1363 N=389 p=.007	.1182 N=389 p=.020	.0884 N=388 p=.082	.1866 N=378 p=.000	.1740 N=389 p=.001	-.0093 N=371 p=.858	.0976 N=384 p=.056	-.0963 N=391 p=.057
Emphasised Process Improvement (V034)	.2231 N=388 p=.000	.2652 N=389 p=.000	.1531 N=389 p=.002	.2633 N=388 p=.000	.2598 N=380 p=.000	.2755 N=389 p=.000	.0083 N=371 p=.874	.2208 N=384 p=.000	.0190 N=391 p=.708
Implementation by consultants (V035)	.0347 N=388 p=.495	.0094 N=390 p=.853	-.0073 N=389 p=.885	-.0189 N=388 p=.710	-.0429 N=378 p=.406	-.0398 N=389 p=.434	.2428 N=371 p=.000	.1245 N=384 p=.015	.1455 N=391 p=.004
Management Commit. (V036)	.3654 N=389 p=.000	.4142 N=390 p=.000	.3183 N=390 p=.000	.4680 N=389 p=0.00	.5220 N=379 p=0.00	.4394 N=390 p=0.00	-.1485 N=372 p=.004	.2187 N=385 p=.000	-.1591 N=392 p=.002
New Culture Emphasis (V037)	.3095 N=387 p=.000	.2970 N=388 p=.000	.2685 N=388 p=.000	.5816 N=389 p=0.00	.3750 N=377 p=.000	.4065 N=388 p=.000	-.0600 N=370 p=.249	.3108 N=383 p=.000	.0224 N=390 p=.659
New Cult Developed (V038)	.5749 N=387 p=0.00	.5969 N=388 p=0.00	.5031 N=388 p=0.00	1.0000 N=390 p= ---	.5920 N=377 p=0.00	.6721 N=388 p=0.00	-.2408 N=370 p=.000	.3699 N=383 p=.000	-.0454 N=390 p=.371
Staff in Planning. (V039)	.3703 N=386 p=.000	.3575 N=387 p=.000	.2903 N=387 p=.000	.4255 N=386 p=.000	.4367 N=376 p=.000	.4203 N=387 p=.000	-.0936 N=369 p=.073	.3123 N=382 p=.000	-.0514 N=389 p=.312
Sustained Imp. (V040)	.5166 N=377 p=0.00	.5233 N=378 p=0.00	.4485 N=378 p=0.00	.5920 N=377 p=0.00	1.0000 N=380 p= ---	.6531 N=379 p=0.00	-.3209 N=364 p=.000	.3267 N=373 p=.000	-.1280 N=380 p=.012
Worker Initiatives (V041)	.4511 N=390 p=0.00	.4782 N=391 p=0.00	.4306 N=391 p=0.00	.5780 N=390 p=0.00	.5708 N=380 p=0.00	.6236 N=391 p=0.00	-.1895 N=373 p=.000	.3197 N=386 p=.000	-.0621 N=393 p=.219
Used Incentives (V042)	.1661 N=386 p=.001	.2066 N=388 p=.000	.1803 N=387 p=.000	.3071 N=386 p=.000	.1515 N=376 p=.003	.2656 N=387 p=.000	.0979 N=369 p=.060	.3219 N=382 p=.000	.0394 N=389 p=.438
Driven by External Support (V043)	-.0255 N=385 p=.618	.0019 N=386 p=.970	.0044 N=386 p=.931	-.0601 N=385 p=.239	-.0688 N=376 p=.183	.0056 N=386 p=.913	.0890 N=369 p=.088	.0668 N=381 p=.193	.0706 N=388 p=.165
Developed Self-improving Org. (V044)	.5647 N=388 p=0.00	.5801 N=389 p=0.00	.4709 N=389 p=0.00	.6721 N=388 p=0.00	.6531 N=379 p=0.00	1.0000 N=391 p= ---	-.2685 N=371 p=.000	.3951 N=384 p=.000	-.0856 N=391 p=.091

	Competitive Advantage (V015)	Performance Enhanced (V016)	Staff Morale Increased (V017)	New Culture Developed (V038)	Sustained Implementation (V040)	Developed Self-improving Org. (V044)	Management Pressure still Needed (V061)	New staff identity developed (V074)	Employees resisted change (V102)
Financial Situation (V045)	.0689 N=375 p=.183	.0165 N=375 p=.750	.0337 N=375 p=.515	-.0016 N=374 p=.976	.0121 N=364 p=.818	.0821 N=375 p=.112	-.0896 N=359 p=.090	.0178 N=370 p=.733	-.1049 N=377 p=.042
Mgmt. Planned Well (V047)	.3542 N=390 p=.000	.3089 N=391 p=.000	.3358 N=391 p=.000	.3884 N=390 p=.000	.3865 N=380 p=.000	.4171 N=391 p=.000	-.2294 N=373 p=.000	.2727 N=386 p=.000	-.1114 N=393 p=.027
Easy for suggestion/improvements. (V048)	.4458 N=390 p=0.00	.4311 N=391 p=0.00	.4618 N=391 p=0.00	.4954 N=390 p=0.00	.5165 N=380 p=0.00	.5195 N=391 p=0.00	-.2783 N=373 p=.000	.3744 N=386 p=.000	-.1130 N=393 p=.025
Culture Initial priority (V049)	.3179 N=389 p=.000	.2918 N=390 p=.000	.3666 N=390 p=.000	.5195 N=389 p=0.00	.4230 N=379 p=.000	.4779 N=390 p=0.00	-.2027 N=372 p=.000	.3641 N=385 p=.000	-.0531 N=392 p=.294
Mgmt. - Effective Comm. Process (V050)	.4564 N=390 p=0.00	.4169 N=391 p=.000	.3574 N=391 p=.000	.5369 N=390 p=0.00	.5156 N=380 p=0.00	.5054 N=391 p=0.00	-.2190 N=373 p=.000	.3418 N=386 p=.000	-.0097 N=393 p=.848
Mngmnt - Vivid Comm. Strategy/Vis] (V051)	.4003 N=389 p=.000	.3823 N=390 p=.000	.2801 N=390 p=.000	.5091 N=389 p=0.00	.4837 N=379 p=0.00	.4946 N=390 p=0.00	-.1813 N=372 p=.000	.3647 N=385 p=.000	-.0042 N=392 p=.934
Management Comm. Staff Role (Alignment) (V052)	.3806 N=389 p=.000	.3775 N=390 p=.000	.3127 N=390 p=.000	.5200 N=389 p=0.00	.5392 N=379 p=0.00	.5469 N=390 p=0.00	-.1734 N=372 p=.001	.3977 N=385 p=.000	-.0366 N=392 p=.470
Mgmt. - Vivid Comm. Steps of Change (V053)	.3763 N=389 p=.000	.3907 N=390 p=.000	.3322 N=390 p=.000	.4313 N=389 p=0.00	.5032 N=379 p=0.00	.4935 N=390 p=0.00	-.1846 N=372 p=.000	.3874 N=385 p=.000	.0079 N=392 p=.877
Mgmt. commit. training (V054)	.3379 N=382 p=.000	.3855 N=383 p=.000	.3473 N=383 p=.000	.4513 N=382 p=0.00	.4500 N=372 p=0.00	.4246 N=383 p=.000	-.1906 N=366 p=.000	.2787 N=378 p=.000	.0026 N=385 p=.959
Mgmt. had excellent lean knowledge (V055)	.3428 N=386 p=.000	.3188 N=387 p=.000	.2367 N=387 p=.000	.3948 N=386 p=.000	.3617 N=376 p=.000	.4058 N=387 p=.000	-.1373 N=369 p=.008	.2298 N=382 p=.000	-.0496 N=389 p=.329
Staff Trusted Mgmt. (V056)	.3618 N=389 p=.000	.3606 N=390 p=.000	.2761 N=390 p=.000	.4564 N=389 p=0.00	.4561 N=379 p=0.00	.4516 N=390 p=0.00	-.1133 N=372 p=.029	.3416 N=385 p=.000	-.1773 N=392 p=.000
Involved all Staff (V057)	.4013 N=375 p=.000	.4163 N=376 p=.000	.4098 N=376 p=.000	.5550 N=375 p=0.00	.4938 N=366 p=0.00	.5298 N=376 p=0.00	-.1174 N=360 p=.026	.3350 N=371 p=.000	-.0071 N=378 p=.891
Lean/flow accounting (V058)	.3430 N=364 p=.000	.3322 N=364 p=.000	.2446 N=364 p=.000	.3478 N=363 p=.000	.3128 N=353 p=.000	.3781 N=364 p=.000	-.0102 N=349 p=.849	.2714 N=361 p=.000	.0077 N=366 p=.884
Flow focus (vs utilisation) (V059)	.3284 N=384 p=.000	.3313 N=384 p=.000	.2321 N=384 p=.000	.3905 N=383 p=.000	.3741 N=373 p=.000	.3696 N=384 p=.000	-.0612 N=369 p=.241	.1997 N=380 p=.000	.0019 N=386 p=.970
Mgmt. Press. was needed (V060)	-.0943 N=385	-.0436 N=386	-.0697 N=386	-.0073 N=385	-.1080 N=375	-.0555 N=386	.6341 N=373	-.0064 N=381	.4280 N=388

	Competitive Advantage (V015)	Performance Enhanced (V016)	Staff Morale Increased (V017)	New Culture Developed (V038)	Sustained Implementation (V040)	Developed Self-improving Org. (V044)	Management Pressure still Needed (V061)	New staff identity developed (V074)	Employees resisted change (V102)
	p=.065	p=.393	p=.172	p=.886	p=.036	p=.277	p=0.00	p=.901	p=.000
Mgmt. Press still Needed (V061)	-.1736 N=370 p=.001	-.1759 N=371 p=.001	-.2569 N=372 p=.000	-.2408 N=370 p=.000	-.3209 N=364 p=.000	-.2685 N=371 p=.000	1.0000 N=373 p= ---	-.1293 N=367 p=.013	.2872 N=373 p=.000
Staff Capability (V062)	.1807 N=389 p=.000	.2228 N=390 p=.000	.1818 N=390 p=.000	.2761 N=389 p=.000	.2899 N=379 p=.000	.3294 N=390 p=.000	-.0997 N=372 p=.055	.1860 N=385 p=.000	-.0972 N=392 p=.055
Technology Capability (V063)	.2139 N=388 p=.000	.2205 N=389 p=.000	.1210 N=389 p=.017	.2160 N=388 p=.000	.2473 N=378 p=.000	.2506 N=389 p=.000	-.1062 N=371 p=.041	.1508 N=384 p=.003	-.1615 N=391 p=.001
Management Capability (V064)	.3145 N=384 p=.000	.2806 N=385 p=.000	.2870 N=385 p=.000	.3954 N=384 p=.000	.4155 N=374 p=.000	.3787 N=385 p=.000	-.1950 N=367 p=.000	.2417 N=380 p=.000	-.1878 N=387 p=.000
Consultant Capability (V065)	.0193 N=292 p=.742	.0718 N=291 p=.222	.0766 N=292 p=.192	-.0077 N=290 p=.896	.0442 N=285 p=.458	.0081 N=291 p=.890	.0941 N=281 p=.115	.1243 N=289 p=.035	-.0233 N=293 p=.691
Implementation Leader Capability (V066)	.3306 N=382 p=.000	.3237 N=383 p=.000	.2264 N=383 p=.000	.3184 N=382 p=.000	.3534 N=373 p=.000	.3454 N=383 p=.000	-.2195 N=365 p=.000	.2475 N=379 p=.000	-.1222 N=385 p=.016
Mgmt. understood tools/methods (V067)	.3424 N=389 p=.000	.3290 N=390 p=.000	.3422 N=390 p=.000	.4059 N=389 p=.000	.3797 N=379 p=.000	.4456 N=390 p=0.00	-.1137 N=372 p=.028	.3038 N=385 p=.000	-.0439 N=392 p=.386
Mgmt. understood as a new culture/philosophy (V068)	.3694 N=389 p=.000	.3507 N=390 p=.000	.3244 N=390 p=.000	.5298 N=389 p=0.00	.4267 N=379 p=.000	.4794 N=390 p=0.00	-.1519 N=372 p=.003	.3750 N=386 p=.000	-.0159 N=392 p=.754
Groups of Positive Staff (V069)	.1482 N=382 p=.004	.1677 N=383 p=.001	.1750 N=383 p=.001	.2441 N=382 p=.000	.2774 N=373 p=.000	.2372 N=383 p=.000	.0592 N=366 p=.259	.2646 N=379 p=.000	.0524 N=385 p=.306
Easy to maintain momentum (V070)	.3779 N=388 p=.000	.4068 N=389 p=.000	.3249 N=389 p=.000	.4069 N=388 p=.000	.4664 N=379 p=0.00	.4401 N=389 p=0.00	-.2177 N=372 p=.000	.3453 N=384 p=.000	-.2146 N=391 p=.000
Fear as a Motivator (V071)	.0273 N=389 p=.592	.0235 N=390 p=.643	.0029 N=390 p=.954	.0211 N=389 p=.679	-.0075 N=379 p=.884	.0354 N=390 p=.485	.2202 N=372 p=.000	.1129 N=385 p=.027	.1860 N=392 p=.000
Small wins prominent (V072)	.2486 N=390 p=.000	.2712 N=391 p=.000	.2813 N=391 p=.000	.3563 N=390 p=.000	.3175 N=380 p=.000	.3378 N=391 p=.000	-.1774 N=373 p=.001	.2495 N=386 p=.000	-.0388 N=393 p=.443
Consultants as a coach. (V073)	.0214 N=378 p=.678	.0579 N=379 p=.261	.0630 N=379 p=.221	.0266 N=378 p=.606	-.0080 N=368 p=.879	-.0213 N=379 p=.680	.1626 N=361 p=.002	.1118 N=376 p=.030	.1257 N=381 p=.014
New staff identity developed (V074)	.2015 N=383 p=.000	.2696 N=384 p=.000	.2733 N=384 p=.000	.3699 N=383 p=.000	.3267 N=373 p=.000	.3951 N=384 p=.000	-.1293 N=367 p=.013	1.0000 N=386 p= ---	.0076 N=386 p=.882

	Competitive Advantage (V015)	Performance Enhanced (V016)	Staff Morale Increased (V017)	New Culture Developed (V038)	Sustained Implementation (V040)	Developed Self-improving Org. (V044)	Management Pressure still Needed (V061)	New staff identity developed (V074)	Employees resisted change (V102)
Growth mindset (can learn/improve) (V075)	.3499 N=385 p=.000	.4116 N=386 p=.000	.3883 N=386 p=.000	.5122 N=385 p=0.00	.4498 N=375 p=0.00	.4877 N=386 p=0.00	-.1710 N=368 p=.001	.5248 N=383 p=0.00	.0463 N=388 p=.363
Staff warned of the struggle (V076)	.2286 N=386 p=.000	.3000 N=387 p=.000	.1950 N=387 p=.000	.2866 N=386 p=.000	.2226 N=376 p=.000	.3078 N=387 p=.000	.0738 N=369 p=.157	.3271 N=384 p=.000	.1418 N=389 p=.005
Guiding coalition supporting. (V077)	.2752 N=387 p=.000	.2511 N=388 p=.000	.2376 N=388 p=.000	.3535 N=387 p=.000	.3745 N=377 p=.000	.3178 N=388 p=.000	-.1101 N=370 p=.034	.3160 N=384 p=.000	.0615 N=390 p=.225
Program/Structure/Regularity (V078)	.3170 N=386 p=.000	.2941 N=387 p=.000	.2475 N=387 p=.000	.3554 N=386 p=.000	.3842 N=376 p=.000	.3371 N=387 p=.000	-.0444 N=369 p=.395	.2945 N=383 p=.000	.0871 N=389 p=.086
Individual support in adjusting (V079)	.3491 N=385 p=.000	.3508 N=386 p=.000	.3299 N=386 p=.000	.4449 N=385 p=0.00	.4152 N=375 p=.000	.4279 N=386 p=.000	-.1152 N=369 p=.027	.4215 N=382 p=.000	.0797 N=388 p=.117
Standard work developed (V080)	.3866 N=389 p=.000	.3322 N=390 p=.000	.2799 N=390 p=.000	.3901 N=389 p=.000	.4463 N=379 p=0.00	.3932 N=390 p=.000	-.0916 N=372 p=.078	.3002 N=385 p=.000	.0673 N=392 p=.184
PCMH (Previous bad experiences) (V084)	-.0829 N=372 p=.110	.0117 N=374 p=.822	-.0369 N=374 p=.477	-.0417 N=372 p=.423	-.0352 N=364 p=.503	-.0727 N=374 p=.161	.1025 N=357 p=.053	-.0610 N=368 p=.243	.3419 N=375 p=.000
Information Systems (V085)	.1458 N=378 p=.004	.1103 N=379 p=.032	.0981 N=379 p=.056	.1402 N=378 p=.006	.1236 N=368 p=.018	.1648 N=379 p=.001	.0807 N=362 p=.125	.2004 N=375 p=.000	.0957 N=381 p=.062
5S System (V086)	.1669 N=383 p=.001	.1289 N=384 p=.011	.1259 N=385 p=.013	.2235 N=383 p=.000	.1349 N=373 p=.009	.2131 N=384 p=.000	.0455 N=366 p=.385	.1683 N=379 p=.001	.1124 N=386 p=.027
Just In Time Manufacture (V087)	.3997 N=381 p=.000	.3672 N=381 p=.000	.2320 N=381 p=.000	.3377 N=380 p=.000	.2851 N=370 p=.000	.3888 N=381 p=.000	-.0640 N=363 p=.224	.2337 N=376 p=.000	.0297 N=383 p=.562
A3 Management, or Nemawashi or Catchball process (V088)	.2074 N=355 p=.000	.1381 N=356 p=.009	.1398 N=358 p=.008	.2325 N=355 p=.000	.1342 N=347 p=.012	.2006 N=357 p=.000	.0665 N=340 p=.221	.1468 N=352 p=.006	.1301 N=358 p=.014
Total Productive Maintenance (V089)	.2903 N=376 p=.000	.2641 N=376 p=.000	.1913 N=376 p=.000	.3107 N=375 p=.000	.2625 N=365 p=.000	.3062 N=376 p=.000	.0140 N=359 p=.792	.2665 N=371 p=.000	.0902 N=378 p=.080
Kaizen (Kaikaku) Improvement Events (V090)	.2458 N=385 p=.000	.2042 N=386 p=.000	.2534 N=387 p=.000	.2767 N=385 p=.000	.1548 N=375 p=.003	.2233 N=386 p=.000	-.0263 N=369 p=.614	.2546 N=381 p=.000	.0906 N=388 p=.075
5 Whys (V091)	.2865 N=383 p=.000	.2710 N=384 p=.000	.2207 N=385 p=.000	.3362 N=383 p=.000	.2576 N=373 p=.000	.2859 N=384 p=.000	-.0711 N=366 p=.175	.1916 N=379 p=.000	.1102 N=386 p=.030
Simple problem solving. (V092)	.3148 N=385 p=.000	.2664 N=386 p=.000	.2530 N=386 p=.000	.4205 N=385 p=.000	.3181 N=375 p=.000	.3925 N=386 p=.000	-.0871 N=368 p=.095	.2816 N=381 p=.000	.0559 N=388 p=.272
Defining Value	.3532	.3676	.2619	.3965	.3961	.3308	-.0464	.2762	.0917

	Competitive Advantage (V015)	Performance Enhanced (V016)	Staff Morale Increased (V017)	New Culture Developed (V038)	Sustained Implementation (V040)	Developed Self-improving Org. (V044)	Management Pressure still Needed (V061)	New staff identity developed (V074)	Employees resisted change (V102)
(V093)	N=384 p=.000	N=385 p=.000	N=385 p=.000	N=384 p=.000	N=374 p=.000	N=385 p=.000	N=368 p=.375	N=380 p=.000	N=387 p=.071
Pull Systems (V094)	.3881 N=382 p=.000	.3821 N=382 p=.000	.2262 N=382 p=.000	.3307 N=381 p=.000	.3566 N=371 p=.000	.3468 N=383 p=.000	-.0849 N=365 p=.105	.1804 N=377 p=.000	.0576 N=384 p=.260
Kanban (V095)	.3415 N=382 p=.000	.2838 N=383 p=.000	.1872 N=384 p=.000	.3129 N=382 p=.000	.2606 N=372 p=.000	.3329 N=383 p=.000	-.1208 N=365 p=.021	.2000 N=378 p=.000	.0595 N=385 p=.244
Statistical Methods (V096)	.2360 N=386 p=.000	.2227 N=387 p=.000	.0976 N=387 p=.055	.2056 N=386 p=.000	.2387 N=377 p=.000	.2595 N=387 p=.000	-.0454 N=370 p=.384	.2251 N=382 p=.000	-.0013 N=389 p=.979
Mapping Value Stream (V097)	.2698 N=389 p=.000	.2866 N=390 p=.000	.2076 N=390 p=.000	.2871 N=389 p=.000	.3024 N=379 p=.000	.2691 N=390 p=.000	-.0476 N=372 p=.360	.2762 N=385 p=.000	.1036 N=392 p=.040
Visual Systems (V098)	.3887 N=390 p=.000	.3303 N=391 p=.000	.2198 N=391 p=.000	.4286 N=390 p=.000	.3534 N=380 p=.000	.3654 N=391 p=.000	-.0344 N=373 p=.508	.1877 N=386 p=.000	.0667 N=393 p=.187
Root Cause Analysis (V099)	.3399 N=390 p=.000	.3234 N=391 p=.000	.2824 N=391 p=.000	.3721 N=390 p=.000	.3676 N=380 p=.000	.4011 N=391 p=.000	-.1161 N=373 p=.025	.2625 N=386 p=.000	.0388 N=393 p=.443
Engaging suppliers (V100)	.3567 N=386 p=.000	.3746 N=387 p=.000	.2576 N=387 p=.000	.3716 N=386 p=.000	.3651 N=376 p=.000	.4051 N=387 p=.000	-.0717 N=369 p=.169	.3064 N=382 p=.000	-.0238 N=389 p=.640
Engaging customers (V101)	.3438 N=386 p=.000	.3519 N=387 p=.000	.2639 N=387 p=.000	.3567 N=386 p=.000	.3918 N=376 p=.000	.3825 N=387 p=.000	-.1494 N=369 p=.004	.2686 N=382 p=.000	-.0275 N=389 p=.589
Employees resisted change (V102)	-.0798 N=390 p=.116	-.1032 N=391 p=.041	-.1329 N=391 p=.009	-.0454 N=390 p=.371	-.1280 N=380 p=.012	-.0856 N=391 p=.091	.2872 N=373 p=.000	.0076 N=386 p=.882	1.0000 N=393 p= ---
Culture similar or conducive already exist.] (V103)	.1038 N=385 p=.042	.0525 N=386 p=.304	.0736 N=386 p=.149	.1114 N=385 p=.029	.1447 N=376 p=.005	.1253 N=386 p=.014	.0425 N=369 p=.416	.1427 N=382 p=.005	-.0557 N=388 p=.273
Staff had KPIs/clear goals (V104)	.4362 N=389 p=0.00	.3932 N=390 p=.000	.3075 N=390 p=.000	.4972 N=389 p=0.00	.5223 N=379 p=0.00	.4885 N=390 p=0.00	-.2030 N=372 p=.000	.3602 N=385 p=.000	-.0011 N=392 p=.982
Mgmt. continued to learn and participate (V105)	.4454 N=388 p=0.00	.4655 N=389 p=0.00	.3742 N=389 p=.000	.5616 N=388 p=0.00	.5886 N=378 p=0.00	.5424 N=389 p=0.00	-.2670 N=372 p=.000	.3556 N=384 p=.000	-.0582 N=391 p=.251
Mgmt. established lean knowledge at start (V106)	.2300 N=389 p=.000	.2333 N=389 p=.000	.1884 N=389 p=.000	.3077 N=388 p=.000	.3424 N=378 p=.000	.2969 N=389 p=.000	-.1310 N=371 p=.012	.2665 N=384 p=.000	-.0943 N=391 p=.063
Work experience (V007)	.1620 N=388 p=.001	.1429 N=389 p=.005	.1440 N=389 p=.004	.1385 N=388 p=.006	.1432 N=379 p=.005	.1548 N=389 p=.002	-.0938 N=371 p=.071	-.0232 N=384 p=.651	-.1081 N=391 p=.033
Implementation	.1746	.1640	.0865	.1735	.2182	.1788	-.0412	.1286	-.0454

	Competitive Advantage (V015)	Performance Enhanced (V016)	Staff Morale Increased (V017)	New Culture Developed (V038)	Sustained Implementation (V040)	Developed Self-improving Org. (V044)	Management Pressure still Needed (V061)	New staff identity developed (V074)	Employees resisted change (V102)
Run time (V028)	N=390 p=.001	N=391 p=.001	N=391 p=.088	N=390 p=.001	N=380 p=.000	N=391 p=.000	N=373 p=.427	N=386 p=.011	N=393 p=.370
Staff meetings. (V081)	-.0545 N=382 p=.288	-.0566 N=383 p=.269	-.0750 N=384 p=.142	-.0947 N=382 p=.064	-.0777 N=373 p=.134	-.0473 N=383 p=.356	.0545 N=366 p=.299	-.0161 N=378 p=.754	-.0695 N=385 p=.173
Performance review/support (V082)	-.1218 N=365 p=.020	-.2100 N=364 p=.000	-.1045 N=365 p=.046	-.2120 N=364 p=.000	-.1316 N=354 p=.013	-.1814 N=365 p=.000	.0653 N=348 p=.224	-.0869 N=359 p=.100	-.0018 N=366 p=.972
Implementation review and planning (V083)	-.1746 N=377 p=.001	-.1770 N=378 p=.001	-.1043 N=378 p=.043	-.2477 N=378 p=.000	-.2163 N=367 p=.000	-.1998 N=378 p=.000	.1155 N=362 p=.028	-.1077 N=373 p=.038	-.0034 N=380 p=.947
Below variables categorical only e.g. Y/N type not suitable for this kind of correlation study									
Internal Lean capability (ex V107) (V134)	.0501 N=193 p=.489	.0286 N=191 p=.694	.0143 N=192 p=.844	-.0073 N=191 p=.920	.0595 N=184 p=.423	.0104 N=191 p=.887	-.0208 N=182 p=.781	.0069 N=190 p=.925	-.1000 N=193 p=.167
Team Focus (ex V107) (V135)	.0228 N=193 p=.753	.0035 N=191 p=.961	.0017 N=192 p=.981	.0715 N=191 p=.326	.0854 N=184 p=.249	.0204 N=191 p=.779	-.0751 N=182 p=.314	-.0246 N=190 p=.736	-.0543 N=193 p=.453
Lean as Cost Cutting (ex V018) (V136)	-.0603 N=95 p=.561	-.0065 N=93 p=.951	-.2793 N=95 p=.006	-.1230 N=94 p=.238	-.1122 N=91 p=.290	-.1694 N=94 p=.103	.1743 N=89 p=.102	-.1701 N=93 p=.103	.0279 N=95 p=.788
Lay off or staff loss (ex V018 or v110) (V137)	.1895 N=189 p=.009	.1708 N=188 p=.019	.0563 N=189 p=.442	.1919 N=189 p=.008	.1155 N=180 p=.122	.1178 N=188 p=.107	.0605 N=179 p=.421	-.0444 N=188 p=.545	.0596 N=190 p=.414
Remove -ve influence (ex V018 or v110) (V138)	.0616 N=189 p=.400	.1062 N=188 p=.147	.0294 N=189 p=.688	.1084 N=189 p=.138	.1074 N=180 p=.151	.0946 N=188 p=.196	-.0521 N=179 p=.489	.0608 N=188 p=.407	-.0551 N=190 p=.451
Lay off, other (ex V018 or v110) (V139)	.1767 N=189 p=.015	.1377 N=188 p=.060	.0477 N=189 p=.515	.1593 N=189 p=.029	.0771 N=180 p=.303	.0858 N=188 p=.242	.0887 N=179 p=.238	-.0734 N=188 p=.317	.0872 N=190 p=.232

Figure 280 Correlation Matrix of Inputs versus outputs (r, N & p).

Tally of Text Responses

Text responses were tallied for common thoughts. Additionally word counts were used to help mine data for specific words found repeating. This also helped guard biasing the tally of common thoughts. See also p. 456.

V018 - Comment on V015-V017	Tally	% of total
Total Comments	208	100%
Other isolated comments or low frequency covered in other q's	69	33.2%
Morale mentioned	45	21.6%
Staff involvement e.g. problem solving is engaging	32	15.4%
Specific improvement notes only	25	12.0%
Performance	15	7.2%
Mixed response from staff (i.e. morale, preferred old way)	11	5.3%
Culture	11	5.3%
Recession/economic climate -negative effect	11	5.3%
Layoff/cost cutting affect Morale/Lean	10	4.8%
Methodology misunderstood by mgmt.	9	4.3%
Competitive mentioned	8	3.8%
Morale dependent on stage an implementation (or person) is at	5	2.4%
Disillusioned	5	2.4%
Different results in different company areas (due to different attitudes/commitment/)	5	2.4%
Not done company wide	4	1.9%
Project in admin.	4	1.9%
Misunderstood study as multiple experiences	3	1.4%
Lose staff	3	1.4%
Creates more tasks and accountability for staff (e.g. recording metrics)	3	1.4%
Communication	3	1.4%
Journey take time to see benefits	3	1.4%
Saved business	2	1.0%
Benefits not delivered	2	1.0%
Essential not merely a Comp Adv.	1	0.5%
High staff turnover negated results	1	0.5%
Lose good staff	1	0.5%
Customers	1	0.5%
Staff feel part of team	1	0.5%
Resistance from threatened management	1	0.5%
Culture first	1	0.5%
Behaviour	1	0.5%
Learn by doing	1	0.5%
Less strain/effort	1	0.5%
Staff excited by the improvement	1	0.5%
Hard to know if lean was what helped. Other variables impacted also	1	0.5%

Unionised negative on morale	1	0.5%
Application is situationally specific	1	0.5%
Momentum	1	0.5%
Recognition	1	0.5%
Dis-benefit	1	0.5%

Figure 281 V018 - Comment on V015-V017—response tally table.: V015 – Competitive Adv. Of Lean, V016 – Performance Enhancement, and V017 – Morale Increased.

V107 - Comment- other important factors (word featured)		
	Tally	% of total
Total	333	100.0%
Management	90	27.0%
Staff or employee or worker	66	19.8%
Train	36	10.8%
Plan or framework or strategy	33	9.9%
Engage	33	9.9%
Plan	28	8.4%
Culture	26	7.8%
Comunic*	24	7.2%
Vision	11	3.3%
Buy => Buy in (mostly ref mgmt.)	11	3.3%
Coach	10	3.0%
Flow	9	2.7%
Visual management	6	1.8%
Toyota	6	1.8%
Strategy	5	1.5%
Framework	4	1.2%
Value stream	3	0.9%
Data	3	0.9%
Waste	2	0.6%
Statistic	1	0.3%

Figure 282 V107 - Comment- other important factors (word featured)—response tally table.

V107 - Comment- other important factors		
	Tally	**% of total**
Total	333	100.0%
Exec/mgmt. Support (include. Patience, confidence, and understanding of lean)	95	28.5%
other	48	14.4%
Mentioned tools/process/technology/methods/Standards in anyway e.g. a tool or the word tool (except for those indicating tools focus	42	12.6%

not important) - most mentions in general way rather than specific tools.		
Staff involvement	39	11.7%
Goals/KPI - business or Employee	32	9.6%
Communication	32	9.6%
Org. develop/culture develop (change mgmt.)	24	7.2%
Networking/mainly suppliers, also others)	22	6.6%
Ongoing training	20	6.0%
Team focus (working together breaking down barriers)	17	5.1%
Internal Lean capability (erg advisors, champion or training)	15	4.5%
Values: e.g. openness/honesty/trust/pride	13	3.9%
Journey Emphasised	10	3.0%
right mix of people	10	3.0%
first results success - gain support	9	2.7%
Align goals	9	2.7%
Communicate wins/results (sometimes good and bad)	9	2.7%
Review progress	9	2.7%
build relationship and engagement between departments	9	2.7%
Visual management	8	2.4%
Strong Consult/Mentor e.g. Toyota culture experience/Cardiff business school	8	2.4%
Urgency (external driver) e.g. customer	8	2.4%
Steering committee/cross ref to guiding coalition… check filled	7	2.1%
Established and holding vision of the future	6	1.8%
Change agents/key leaders/people	6	1.8%
Responsibility/accountability assigned	5	1.5%
Strong urgency/passion/determination internally	5	1.5%
Own system name or terminology (e.g. vs lean and Japanese language)	5	1.5%
voice of customer - knowledge of market	5	1.5%
Cross functional teams, e.g. "The best ideas often came from someone outside that department/line of work."	4	1.2%
Financial support (e.g. government support for training)	4	1.2%
GEMBA/management by walking around	4	1.2%
100% allocation to improvements (else not getting done)	4	1.2%
Particular Training for leaders	3	0.9%
Hoshin Kanri, true north	3	0.9%
Engagement of all up front (selling the idea)	3	0.9%
Cross training/up-skill/multiskilling	3	0.9%
Systems thinking (concept)	3	0.9%
Establishment of Centre of excellence	3	0.9%
Redundancies in mgmt. (road blocks removed-encourage staff")	3	0.9%
Remove -ve influences, non-cooperative (mostly mgmt.)	3	0.9%
Standard work	2	0.6%
Good financial performance	2	0.6%
Better in touch with market	2	0.6%
Not cost cutting e.g. redundancies	2	0.6%
Budget/significant budget	2	0.6%

Incentives	2	0.6%
Fear of job loss as motivator	2	0.6%
Training materials	2	0.6%
Simple approach	2	0.6%
Address opportunities (e.g. identified by staff),not just train for training sake	2	0.6%
Understanding waste	1	0.3%
Design for Six-Sigma implementation plan	1	0.3%
Recession, diligence to keep job	1	0.3%
No incentives for Lean (part of job)	1	0.3%
Kanban core/removal of ERP in manufacture planning	1	0.3%
Focus on strengths	1	0.3%
CFO Lead	1	0.3%
Simulation	1	0.3%
Greenfield site	1	0.3%
None	1	0.0%

Figure 283 V107 – Comment: other important factors—response tally table.

V107 - Negative Comments	**Tally**	**% of total**
Total	333	100.0%
Management support poor	13	3.9%
Management understanding poor	8	2.4%
Changes of leadership… stop start and poor leadership	3	0.9%
Management not changing behaviour	2	0.6%
No goals set	2	0.6%
Responsibility delegated	2	0.6%
Cost cutting exercise	2	0.6%
Culture change not understood	1	0.3%
Pride	1	0.3%
But were re-educated	1	0.3%
But other supportive agent	1	0.3%
Driven from the floor and a disaster	1	0.3%
Top down… without bottom up	1	0.3%
Vision not clearly communicated to middle mgmt.	1	0.3%
Methods only approach	1	0.3%
Lack of trust	1	0.3%
Departmental boundaries	1	0.3%
Share price driven	1	0.3%
Day to day was highest priority rather than Lean	1	0.3%
No urgency/no external drive	1	0.3%
Complex equipment	1	0.3%
Inexperienced consultant	1	0.3%
Lean and SS separated - not integrated	1	0.3%

Figure 284 'V107 - Negative Comments—response tally table.

"Methodology was less important than the recognition that managers needed to manage change."
I was under a lot of pressure from the business to move quicker but knew this would lead to a sustainable and owned solution which it did.
Senior Executive commitment is not enough. They must actively lead "elements of the transition and be seen to do so. They must 'walk the talk' as the cliche goes. " "focus on developing a competent and highly functional executive leadership team - to drive and support the implementation; to fully understand the time and commitment required and to ensure ongoing priority and momentum is maintained and sustained"
Balancing changes which make an immediate impact with long term strategy.
Many people were stuck in their ways of doing things and had difficulty accepting that things could be done better - "we've tried that before and it didn't work"
Lower focus on specific tools and greater focus on team Commitment & Leadership - fundamental
Points of note: - Management has zero knowledge of Lean besides having viewed a facsimile of the "TPS House" - All planning, leading and implementation is delegated by management in a hands-off approach to a few staff, none of whom have any experience in leading Lean implementation, or any formal training in same - Day to day crises are deemed unambiguously higher priority than any effort spent on Lean - Initiative is several months old as at writing - More than half of the initial group have departed the organisation
Unfortunately the Lean implementation for some very daft reason stopped at the end of the final assembly of the product. Another "re-engineering" project (Order-to-Delivery) was responsible for outbound distribution. They promised a lot, strutted their stuff and delivered zilch. The two projects should have been one but the cultures were diametrically opposed which was a major blunder. I suspect part of this was due to very strong territoriality by some functions (very much like big cats marking their territory).

Figure 285 V107—Quotes

V108 Do differently.	**Tally**	**% of tallied**
Not all comments tallied but all responses were reviewed with no particularly new or interesting concepts introduced after the last tallied entry i.e. except for two recorded as quotes. Answers did not warrant any impact/adjustment to data set or other changes related to statistical analysis.		
Total Comments	369	N/A
Total tallied	171	100.0%
Other	46	26.9%
Addresses management	41	24.0%
Nothing	18	10.5%
More staff involvement	14	8.2%
Review (e.g. with stakeholders and progress on goals)	10	5.8%
Plan more	9	5.3%
Confidence, get in there and do it, plan less, speed up	8	4.7%
Start small/manageable change	6	3.5%
No consultant reliance/coach only	5	2.9%
Pre-evaluate	5	2.9%
Goals	5	2.9%
Management KPIs	4	2.3%
Discipline/remove negative/underperformers earlier	4	2.3%
Standards/processes - ongoing standard work (should review responses with this in mind or do "word featured" count	3	1.8%
Get consultant/outside support or influence	2	1.2%
Customer	2	1.2%
Commitment - including funds	2	1.2%
Celebrate wins	2	1.2%
Train lowest leadership level only	1	0.6%
Every time different approach	1	0.6%
Other priorities impacted implementation	1	0.6%

Figure 286 V108 Do differently—response tally table.

V108 - Quotes
Would evaluate the executive leadership first - if they don't get Lean, don't bother trying to use it to make improvements
I would have introduced the program to our customers differently, and I wouldn't have called it a "lean" program.
Implement from the ground up, team by team, avoiding senior management involvement as much as possible.
1. I would encourage other plants to select their "most valuable employees" who had already established "credibility" based on their past successes to be the selected candidates for training. 2. I would train candidates first in Office based computer software including: word, excel, powerpoint prior to entering them into formal Six Sigma Training. 3. I would provide outside "Minitab" training at a University level as a part of the training process to select candidates to create a statistical champion in the team. 4. I would recommend that and Six Sigma team be provided with their own open office work space and have weekly meetings formalized with onsite senior management. 5. There needs to be a plan established on how Six Sigma team members will be reintegrated into the plant or corporate staff after 1 to 3 years of project team work to open up opportunities for others and also spread "trained managers" back into the corporate organizational structure.
1. The Lean Champions were supposedly volunteers but some of the were voluntolds. I would prefer to have Team Leaders/Managers as the Champions. The results are then aligned with their KPIs and it's easier for Managers to getb the buy in 2. Champions chose their own Kaizen topics. I would set up a series of "campaigns" that takes them through a Lean implementation in a structured way

Figure 287 V108–Quotes

V108 -Word featured	Tally	% of Total
Total Comments	369	N/A
Management	86	23.3%
Staff or employee or worker	63	17.1%
Train	52	14.1%
Plan Strategy Framework	43	11.7%
Communic	31	8.4%
Engage	22	6.0%
Culture	21	5.7%
coach	12	3.3%
Educat	8	2.2%
Vision	6	1.6%
Buy => Buy in (~50% mgmt. ref)	6	1.6%
Visual management	4	1.1%
Value stream	4	1.1%
Statistic	3	0.8%
Waste	3	0.8%
Flow	3	0.8%
Toyota	1	0.3%
Data	1	0.3%
Kanban	0	0.0%

Figure 288 V108 -Word featured—response tally table.

V109 Significant positive outcomes	Tally	% of Tallied
Total Comments	410	N/A
Total text responses tallied	50	100.0%
Additionally (some noted embedding of certain tools, ability to plan, staff trained, systems thinking (company as a whole/team view), reduction in risk, meeting standards i.e. iso, and better usage of in-house talent.		
Culture/morale	21	42.0%
Financial: Profit/cost/growth/sales/productivity	20	40.0%
Quality/Service	13	26.0%
Delivery	10	20.0%
Customer	8	16.0%
General/other	7	14.0%
Inventory/WIP	6	12.0%
Awareness (e.g. problems to solve)	5	10.0%
Plant/Presentation/	3	6.0%
Safety	2	4.0%
Capacity	2	4.0%
Ideas - improvement initiatives	1	2.0%

Figure 289 V109 Significant positive outcomes—response tally table.

V110 Significant negative outcomes	**Tally**	**% of Tallied**
Total Comments	310	N/A
Total tallied	64	100.0%
Some included incentive plans, transition from phase to phase/handovers, division in ranks between Lean/LSS and SS, tall poppy syndrome, management claiming credit but not involved, increased ownership vs standard work, restructuring downsizing etc. mid-implementation or as part of greater strategy (i.e lean not the strategy) results not delivered fast enough so CEO removed and initiative dropped, public accountability versus too much criticism and airing dirty laundry, specialist departing due to no ladder to climb or feeling no place for them in the company, also staff were well trained in some cases and demand grew for them (e.g. Lean talent) elsewhere so they left, old habits, roles not defined so stressful, them vs us, external changes outpacing lean, different between finance perspective and culture development in redundancies, management attitude included lack of support, 5S alone e.g. office creating negative change history without full view, split between thinking the change would have happened anyway, individual vs team performance reviews, increased meetings (daily) disturbing daily work, increased wage expectations, rotating shift patterns wearing out staff, focus on productivity and cost cutting but not enough on people, In comments here and elsewhere middle manager problems reared as much as senior management they were not engaged, afraid, did not understand, did not support etc. i.e. top wanted and bottom wanted but middle blocked. Transition from kaizen initiative to regular schedule, the language used (mumbo jumbo), too much change wearied staff (even for changes they initiated), also management not able to get lean to work "their way" so stopped believing, not dealing with negative influences, **a number of comments indicated initial struggles but eventual success.**		
Staff turnover some positive and negative e.g. cost cutting and fear created even when just removing resistant team members	17	26.6%
None	12	18.8%
management attitude	9	14.1%
Frustration/resistance/change stress	8	12.5%
Time frame	5	7.8%
Contributed to PCMH/just another fad, unstained	4	6.3%
General/other	3	4.7%
Unresolved relationships - e.g. persons and departments	2	3.1%
Increased work	2	3.1%
Closures	2	3.1%
Cost	2	3.1%
Should have done sooner	1	1.6%
Sales didn't increase to new capacity	1	1.6%
Differences by geography	1	1.6%
Aging workforce	1	1.6%

Figure 290 V110 Significant negative outcomes—response tally table.

V132 - Final Comment	Tally	% of Total
Content included: lean used as buzz word, should develop own internal capability of empowered staff, management attitude and survey design		
Total Comments	158	
Positive about the questionnaire	13	4.2%
Negativity to survey length or display clarity	10	3.2%
Negativity to survey specifically understanding of Lean	4	1.3%
Negativity about general survey method taken	3	1.0%
Lean in NZ	2	0.6%
Survey layout comments	0	0.0%

Figure 291 V132 - Final Comment—response tally table.

Specific Text Response Variables

Specific variables were extracted from free text responses. These variables have implications for possible further work as their frequency was relatively high.

Percentage of occurrence is seen in Figure 292. The questions were coded in the following manner. If a thought was present in the comment it was recorded as 1 (= yes), if a comment was made but didn't include that thought that was a 0 (= No).

11% of participant comments (V018 and V110) mentioned staff loss. The coded variables Lay off or Staff loss (V137), and Lay off other (V139) were in the negative sense covered by V071 - Fear as a motivator, which had the specific demarcation of job or income loss. Coding these comments did allow some rough comparisons on variations of this in following charts.

It would have been beneficial to see the effect of removing persons who were negative influences (V138). This is quite situationally specific as the relatively low frequency of comments (1.6%) suggest. If the success factors are valued and management capabilities are developed then such persons would not fit and not be tolerated.

Developing the internal Lean Capability (V134) was in a broad sense covered by staff (V62), management (V64), and lean leader (V66) capability along with mentions of coaching and training and the building of a Guiding coalition (V077) which develops the internal capability. Team Focus (v135) is included as part of employees engagement and empowerment, Worker Initiatives (V041), Involved all Staff (V057) along with multiple communication variables. The concept of Lean as Cost Cutting (V136) was not alluded to solidly in the study however, the importance of the opposite was emphasised.

Although these variables were not covered thoroughly by the survey their relative frequency is low (e.g. 2 to 5% of comments for these variables, as opposed to 29% of the comments reinforcing management support as important, a variable already covered in the survey).

Comment Common Thought	Tally	% of Total for that question
V134 -Internal Lean capability (e.g. advisors, champion or training) (comment ex V107)	15	4.5%
V135 -Team Focus (working together breaking down barriers)(comment ex V107)	17	5.1%
V136 -Lean as Cost Cutting e.g. Layoff affect morale (V018)	10	4.8%
V137 -Lay off or staff loss (comment ex V018 or v110)	42	11.2%
V138 -Remove -ve influence/incompatible persons (comment ex V018 or v110)	6	1.6%
V139 - Employee lay off, other (comment ex V018 or v110)	36	9.6%
Values: e.g. openness/honesty/trust/pride (ex V107)	13	3.9%
Right mix of people(ex V107)	10	3.0%
Build relationship and engagement between departments (ex V107)	9	2.7%
Strong Consult/Mentor e.g. Toyota culture experience/Cardiff business school (ex V107)	8	2.4%
Urgency (external driver) e.g. customer	8	2.4%
Ongoing training (ex V107)	20	6.0%
Recession/economic climate -negative effect (ex V018)	11	5.3%
Exec/mgmt. Support (including patience, confidence, and understanding of lean) (ex V107)	95	28.5% (this tally for cross reference as was also a survey question)
Communication (Ex V 107)	32	9.6% (this tally for cross reference as was also a survey question)

Figure 292 Table shows text response of specific insight and relative frequency.

Participant's Experience

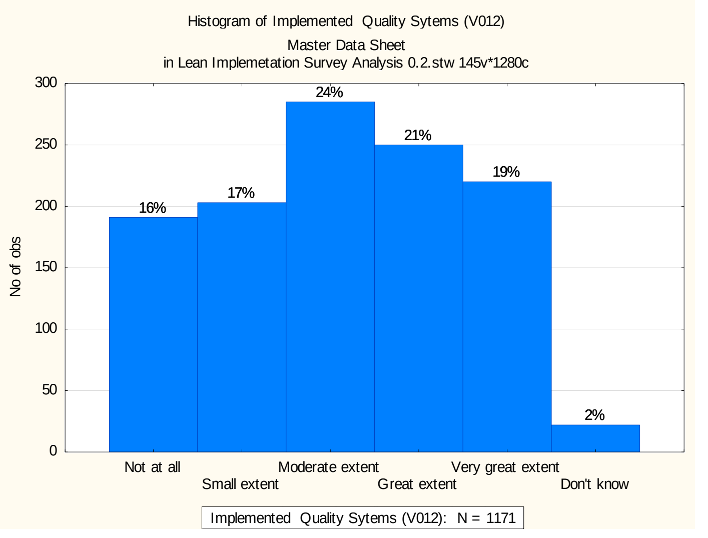


Figure 293 Participant experience implementing Quality Systems (all data).

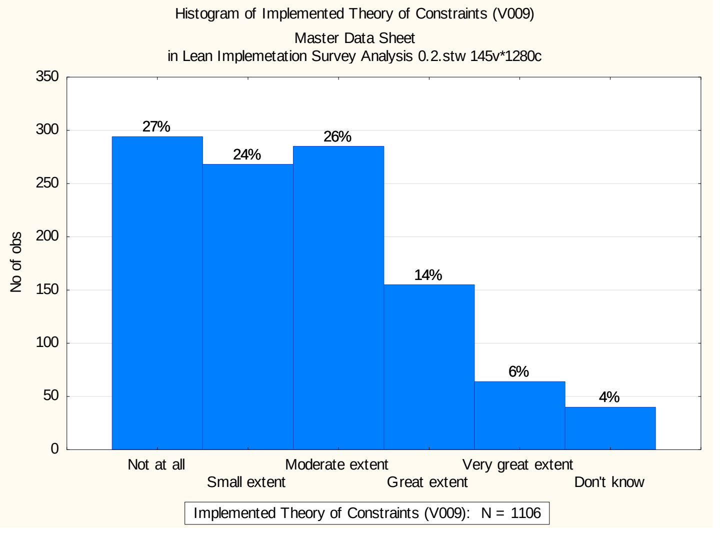


Figure 294 Participant experience implementing Theory of Constraints (all data).

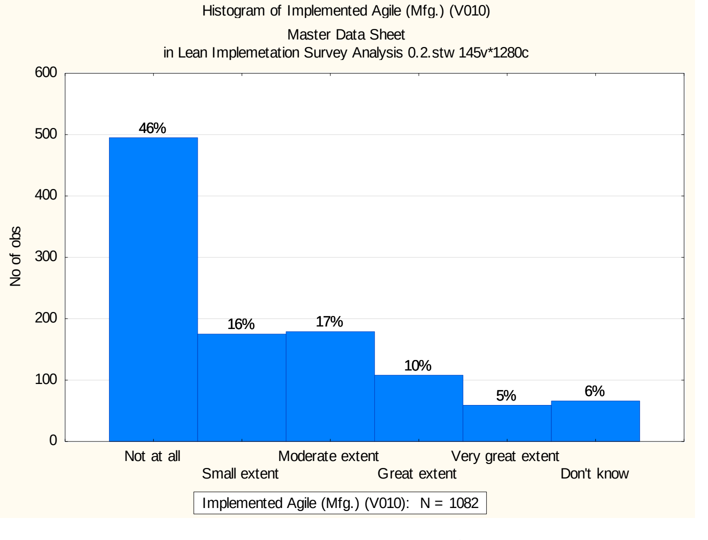


Figure 295 Experience implementing Agile Manufacturing (all data).

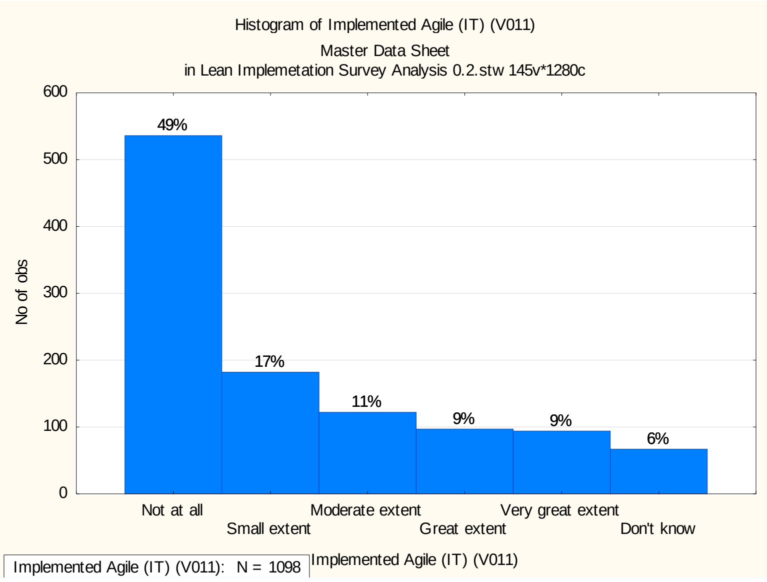


Figure 296 Experience implementing Agile for IT (all data).

Erroneous Cases

Erroneous cases were removed from analysis (see V141 and V142). Cases were removed primarily because participants expressed that that their response did not conform to the survey case. The reasons are seen in Figure 297. Five participants commented that they decided to fill the survey with multiple implementations in view. Although these implementations may have been similar in their mind that is not the way the study was intended and answers may have been slightly skewed to conform to the multiple cases considered. Three participates expressed that their results were affected by other factors. Although that may not have caused bias, because of their expressly mentioning them the removal of their case was compelled. They deemed themselves that the representative output was not from the input being measured, this similarly for one case where the business was closing. In two cases morale it was indicated that morale could not be improved and one case where lean was expressed as being no competitive advantage. These three cases could possibly have been included in the overall analysis but due to the large available set, these few responses were quickly removed as deemed to have an insignificant effect on the overall study.

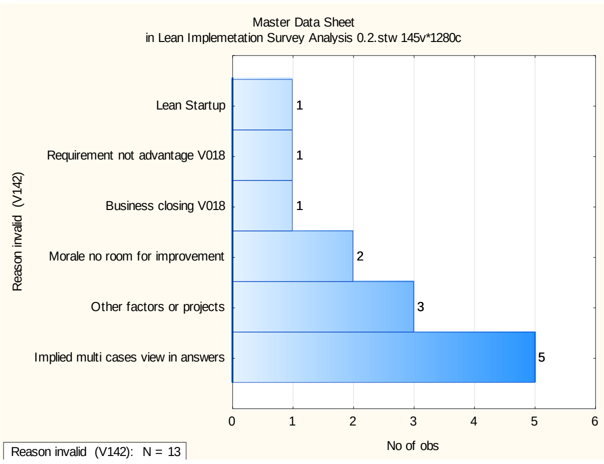


Figure 297 Reason case responses removed as "Invalid" (V142)

Lean to Lean Six-sigma Comparisons

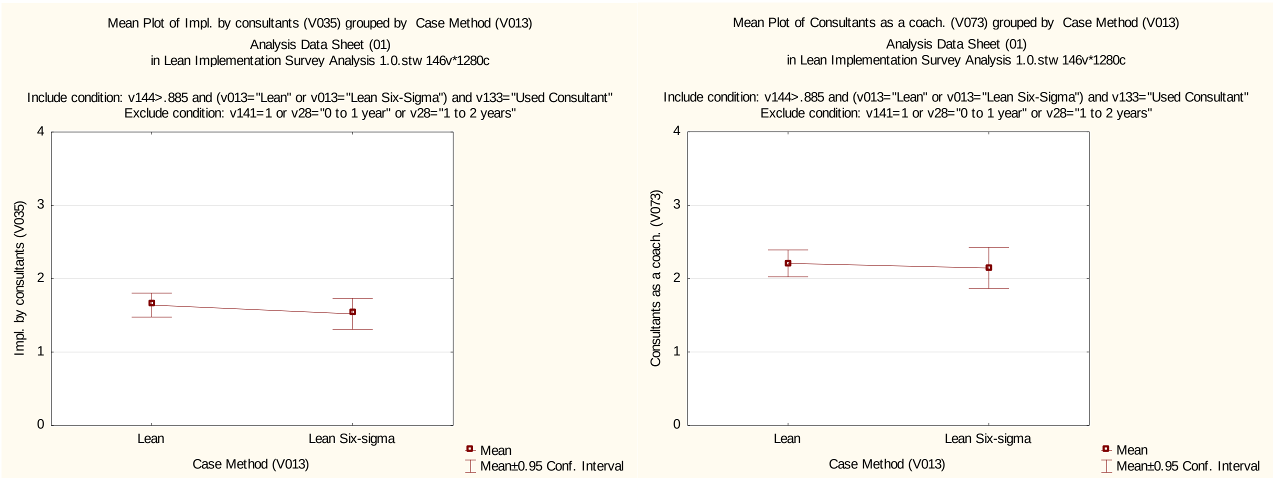


Figure 298 Lean to lean six sigma comparisons by consultant as coach and implemented by consultant.

Ambiguity of Term: Staff vs Employee

One email query came from a respondent regarding the definition of “staff” i.e. whether or not staff referred to all employees or just management based on what they considered the American definition of staff. By looking at answer, it was deemed an isolated response. Up to that response (122), it was found 50 filled responses and only six cases that listed less than 50 “staff”, a high number to be representing only management team. Of these cases only one represented the United States, two cases had 40 staff and one 30, with the lowest being 10. This is tabulated below in Figure 299. This said the question was adjusted and clarified from that point. Some responses indicated they were answering for an approach used across different businesses and possibly different results somewhat these cases were removed from the study.

Country (V005)	Staff No. (V027)
New Zealand	30
India	40
United States	10
United Kingdom	40
Brazil	15
United States	10

Figure 299 Staff number by Country for Staff No. < 50 in first 122 responses, 50 filled responses. Table used as example of how ambiguity was considered.

13.2.3 SEM Quality Validation

The following tables are quality analysis outputs, see questionnaire One for details of interpretation (p. 182).

Quality Analysis: SEM A—Simplistic Model

Quality validation for SEM A.2 is given below.

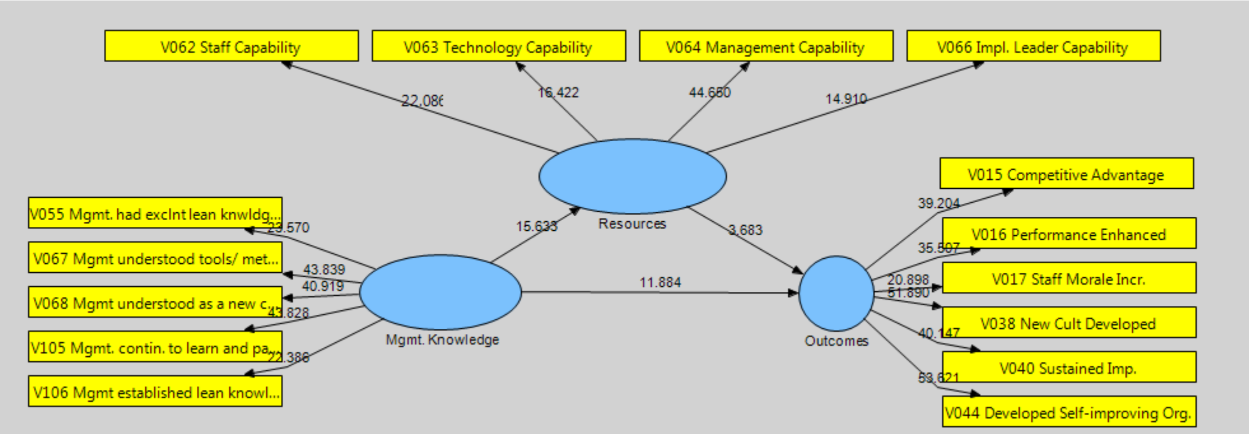


Figure 300 SEM A.2 bootstrapped (5000 times, no sign changes allowed) model showing t-statistics: all paths highly significant to p<0.001.

SEM K.1 Model Validation

	5S	Communication	Employee Initiatives (Enabled)	Engage Customers	Engage Suppliers	Guiding Coalition	JIT	Journey View	Kaizen Events	Lean/Flow Accounting	Management Knowledge	Outcomes	Planning	Problem Solving (Simple)	Pull/Kanban	Regularity	Standard Work	Statistical Methods	Support Employees	TPM	Value Flow	Visual Systems
5S V086 5S System	1.00	0.26	0.40	0.06	0.22	0.19	0.48	0.29	0.48	0.20	0.30	0.16	0.19	0.43	0.41	0.27	0.36	0.20	0.23	0.52	0.25	0.53
COM V050 Mngmnt effective co	0.22	0.88	0.66	0.37	0.42	0.37	0.36	0.36	0.25	0.33	0.55	0.54	0.63	0.35	0.34	0.46	0.39	0.21	0.50	0.30	0.38	0.39
COM V051 Mngmnt vivid comm.	0.20	0.91	0.63	0.38	0.38	0.34	0.34	0.36	0.29	0.36	0.60	0.52	0.56	0.34	0.37	0.43	0.40	0.22	0.52	0.35	0.40	0.37
COM V052 Mngmnt comm. staff	0.25	0.91	0.69	0.44	0.46	0.38	0.39	0.34	0.29	0.42	0.63	0.53	0.63	0.39	0.40	0.47	0.40	0.23	0.54	0.42	0.38	0.36
COM V053 Mngmnt vivid com. s	0.25	0.86	0.63	0.37	0.37	0.41	0.34	0.34	0.29	0.32	0.57	0.49	0.64	0.35	0.36	0.50	0.39	0.20	0.49	0.39	0.39	0.37
EE V041 Worker Initiatives	0.31	0.53	0.82	0.37	0.31	0.38	0.33	0.46	0.31	0.33	0.57	0.57	0.42	0.49	0.27	0.49	0.46	0.16	0.57	0.34	0.38	0.45
EE V048 Easy for suggestion/imp	0.29	0.65	0.83	0.30	0.35	0.43	0.34	0.41	0.23	0.29	0.62	0.55	0.63	0.36	0.35	0.46	0.40	0.14	0.56	0.27	0.29	0.31
EE V057 Involved all Staff	0.39	0.64	0.83	0.30	0.37	0.40	0.40	0.47	0.35	0.44	0.60	0.51	0.49	0.49	0.37	0.49	0.49	0.14	0.57	0.41	0.33	0.52
ENC V101 Engaging customers	0.06	0.44	0.39	1.00	0.59	0.19	0.26	0.25	0.18	0.29	0.39	0.44	0.33	0.32	0.23	0.29	0.28	0.25	0.39	0.25	0.41	0.25
ENS V100 Engaging suppliers	0.22	0.46	0.41	0.59	1.00	0.22	0.48	0.19	0.17	0.36	0.42	0.44	0.35	0.28	0.47	0.29	0.35	0.38	0.40	0.38	0.41	0.35
GC V077 Guiding coalition suppor	0.19	0.42	0.49	0.19	0.22	1.00	0.19	0.35	0.21	0.11	0.44	0.35	0.39	0.38	0.23	0.60	0.42	0.20	0.53	0.23	0.37	0.40
JIT V087 Just In Time Manufactu	0.48	0.40	0.43	0.26	0.48	0.19	1.00	0.30	0.44	0.35	0.43	0.40	0.35	0.35	0.66	0.27	0.35	0.22	0.31	0.55	0.38	0.42
JV V031 JourneyView	0.29	0.39	0.54	0.25	0.19	0.35	0.30	1.00	0.24	0.19	0.49	0.40	0.30	0.47	0.20	0.43	0.36	0.14	0.41	0.23	0.29	0.46
KAI V090 Kaizen	0.48	0.31	0.36	0.18	0.17	0.21	0.44	0.24	1.00	0.25	0.29	0.22	0.20	0.50	0.48	0.35	0.31	0.16	0.34	0.51	0.42	0.33
LAC V058 Lean/flow accounting	0.20	0.40	0.42	0.29	0.36	0.11	0.35	0.19	0.25	1.00	0.46	0.38	0.31	0.25	0.38	0.17	0.36	0.28	0.30	0.40	0.25	0.24
MK V067 Mngmnt understood to	0.30	0.48	0.57	0.26	0.32	0.30	0.36	0.36	0.24	0.46	0.84	0.41	0.46	0.35	0.36	0.34	0.43	0.21	0.42	0.35	0.24	0.40
MK V068 Mngmnt understood as	0.27	0.56	0.60	0.33	0.33	0.39	0.37	0.44	0.28	0.39	0.87	0.44	0.47	0.44	0.34	0.44	0.45	0.17	0.56	0.34	0.34	0.42
MK V105 Mngmnt contin. to lear	0.20	0.62	0.65	0.40	0.40	0.42	0.35	0.44	0.22	0.33	0.82	0.59	0.49	0.47	0.40	0.49	0.44	0.32	0.58	0.34	0.37	0.48
OC V016 Performance Enhanced	0.13	0.44	0.55	0.37	0.38	0.26	0.37	0.29	0.21	0.34	0.47	0.89	0.33	0.30	0.40	0.32	0.33	0.24	0.46	0.27	0.38	0.35
OC V040 Sustained Imp.	0.16	0.59	0.64	0.42	0.40	0.36	0.30	0.39	0.14	0.32	0.57	0.83	0.45	0.34	0.32	0.43	0.43	0.24	0.52	0.27	0.38	0.34
OC V015 Competitive Advantage	0.13	0.46	0.49	0.35	0.35	0.28	0.38	0.36	0.24	0.31	0.43	0.86	0.37	0.34	0.40	0.34	0.38	0.25	0.39	0.29	0.36	0.38
PL V047 Mngmnt planned well	0.19	0.69	0.62	0.33	0.35	0.39	0.35	0.30	0.20	0.31	0.56	0.45	1.00	0.36	0.34	0.38	0.34	0.20	0.45	0.27	0.29	0.32
PR V091 5 Whys	0.41	0.35	0.45	0.26	0.24	0.32	0.33	0.39	0.53	0.23	0.43	0.32	0.28	0.91	0.42	0.42	0.35	0.30	0.39	0.46	0.41	0.50
PR V092 Simple problem solving	0.36	0.37	0.54	0.32	0.27	0.38	0.31	0.46	0.37	0.22	0.48	0.37	0.38	0.90	0.34	0.44	0.38	0.29	0.50	0.40	0.45	0.54
PUL V094 Pull Systems	0.33	0.39	0.38	0.25	0.42	0.25	0.58	0.20	0.44	0.33	0.40	0.43	0.29	0.41	0.91	0.27	0.37	0.27	0.38	0.45	0.51	0.44
PUL V095 Kanban	0.43	0.36	0.35	0.17	0.42	0.18	0.62	0.17	0.42	0.36	0.39	0.35	0.32	0.35	0.90	0.19	0.31	0.37	0.34	0.50	0.36	0.37
REG V072 Small wins prominent	0.21	0.38	0.48	0.23	0.21	0.35	0.21	0.37	0.31	0.07	0.36	0.31	0.22	0.36	0.12	0.78	0.36	0.11	0.45	0.20	0.28	0.35
REG V078 Program/Structure/Re	0.24	0.47	0.48	0.24	0.27	0.61	0.23	0.34	0.27	0.20	0.47	0.39	0.39	0.41	0.28	0.86	0.48	0.27	0.52	0.33	0.38	0.41
STA V096 Statistical Methods	0.20	0.24	0.17	0.25	0.38	0.20	0.22	0.14	0.16	0.28	0.28	0.28	0.20	0.32	0.35	0.24	0.26	1.00	0.29	0.32	0.35	0.22
STW V080 Standard work develo	0.36	0.44	0.54	0.28	0.35	0.42	0.35	0.36	0.31	0.36	0.52	0.44	0.34	0.40	0.38	0.52	1.00	0.26	0.48	0.40	0.33	0.53
SU V075 Growth mindset	0.22	0.54	0.65	0.32	0.34	0.42	0.29	0.37	0.28	0.29	0.62	0.48	0.39	0.42	0.36	0.50	0.42	0.26	0.89	0.30	0.47	0.41
SU V079 Individual support in adj	0.17	0.46	0.54	0.36	0.35	0.51	0.24	0.34	0.32	0.23	0.45	0.44	0.39	0.43	0.32	0.54	0.40	0.25	0.85	0.24	0.39	0.39
TPM V089 Total Productive Mai	0.52	0.41	0.41	0.25	0.38	0.23	0.55	0.23	0.51	0.40	0.41	0.32	0.27	0.47	0.52	0.33	0.40	0.32	0.31	1.00	0.35	0.47
V093 DefiningValue	0.19	0.43	0.36	0.36	0.34	0.33	0.35	0.31	0.41	0.19	0.36	0.44	0.26	0.45	0.43	0.36	0.32	0.30	0.46	0.32	0.89	0.35
V097 MappingValue Stream	0.25	0.34	0.35	0.37	0.38	0.32	0.32	0.19	0.33	0.24	0.31	0.32	0.26	0.39	0.41	0.36	0.27	0.32	0.42	0.29	0.87	0.44

Variables must load their consruct higher than any c Values > 0.6 highlighted

Figure 301 SEM K.1 indicator cross loadings

Negative relationships and p>0.01 highlighted	Original Sample (β)	Sample Mean	Standard Deviation	Standard Error	T Statistics	p -value (Significance)
5S->Outcomes	-0.17	-0.17	0.05	0.05	3.55	0.00043
Communication->Employee Initiatives (Enabled)	0.36	0.36	0.04	0.04	9.36	0.00000
Communication->Engage Customers	0.17	0.17	0.05	0.05	3.43	0.00067
Communication->Engage Suppliers	0.26	0.26	0.05	0.05	4.81	0.00000
Communication->Regularity	0.22	0.22	0.05	0.05	4.34	0.00002
Communication->Value Flow	0.20	0.20	0.06	0.06	3.36	0.00087
Employee Initiatives (Enabled)->Outcomes	0.56	0.56	0.04	0.04	13.26	0.00000
Engage Customers->Outcomes	0.18	0.18	0.04	0.04	4.71	0.00000
Engage Suppliers->Engage Customers	0.44	0.44	0.06	0.06	8.04	0.00000
Guiding Coalition->Regularity	0.36	0.36	0.05	0.05	7.06	0.00000
Guiding Coalition->Value Flow	0.18	0.18	0.05	0.05	3.66	0.00029
JIT->Engage Suppliers	0.30	0.30	0.05	0.05	5.75	0.00000
JIT->Pull/Kanban	0.58	0.58	0.04	0.04	14.68	0.00000
Journey View->Employee Initiatives (Enabled)	0.18	0.18	0.03	0.03	5.99	0.00000
Kaizen Events->TPM	0.32	0.32	0.06	0.06	5.73	0.00000
Lean/Flow Accounting->JIT	0.20	0.20	0.05	0.05	3.65	0.00030
Lean/Flow Accounting->Statistical Methods	0.18	0.18	0.05	0.05	3.23	0.00135
Lean/Flow Accounting->TPM	0.21	0.21	0.05	0.05	4.24	0.00003
Management Knowledge->Communication	0.40	0.40	0.04	0.04	9.54	0.00000
Management Knowledge->Employee Initiatives (Enabled)	0.24	0.24	0.04	0.04	5.38	0.00000
Management Knowledge->Guiding Coalition	0.33	0.33	0.06	0.06	5.95	0.00000
Management Knowledge->JIT	0.34	0.34	0.05	0.05	7.34	0.00000
Management Knowledge->Journey View	0.37	0.37	0.05	0.05	7.95	0.00000
Management Knowledge->Lean/Flow Accounting	0.46	0.46	0.04	0.04	11.71	0.00000
Management Knowledge->Planning	0.56	0.56	0.04	0.04	14.95	0.00000
Management Knowledge->Problem Solving (Simple)	0.24	0.24	0.04	0.04	5.62	0.00000
Management Knowledge->Pull/Kanban	0.19	0.19	0.04	0.04	4.53	0.00001
Management Knowledge->Standard Work	0.34	0.34	0.05	0.05	6.51	0.00000
Management Knowledge->Support Employees	0.39	0.38	0.04	0.04	9.12	0.00000
Management Knowledge->Visual Systems	0.40	0.40	0.05	0.05	8.22	0.00000
Planning->Communication	0.46	0.46	0.04	0.04	11.44	0.00000
Planning->Guiding Coalition	0.20	0.20	0.05	0.05	3.73	0.00022
Problem Solving (Simple)->Kaizen Events	0.36	0.36	0.05	0.05	6.99	0.00000
Problem Solving (Simple)->Regularity	0.17	0.17	0.04	0.04	3.79	0.00018
Pull/Kanban->Kaizen Events	0.32	0.32	0.05	0.05	6.85	0.00000
Pull/Kanban->Outcomes	0.23	0.23	0.04	0.04	5.32	0.00000
Pull/Kanban->Statistical Methods	0.29	0.28	0.06	0.06	5.18	0.00000
Pull/Kanban->TPM	0.29	0.29	0.05	0.05	5.60	0.00000
Pull/Kanban->Value Flow	0.30	0.30	0.05	0.05	5.75	0.00000
Pull/Kanban->Visual Systems	0.27	0.27	0.05	0.05	5.33	0.00000
Regularity->Journey View	0.24	0.24	0.05	0.05	4.84	0.00000
Regularity->Support Employees	0.30	0.30	0.04	0.04	6.79	0.00000
Standard Work->Regularity	0.20	0.20	0.06	0.06	3.57	0.00041
Statistical Methods->Value Flow	0.16	0.16	0.05	0.05	3.16	0.00169
Support Employees->Employee Initiatives (Enabled)	0.26	0.26	0.04	0.04	6.03	0.00000
TPM->5S	0.35	0.35	0.05	0.05	6.93	0.00000
Value Flow->Engage Customers	0.16	0.16	0.05	0.05	3.31	0.00101
Value Flow->Engage Suppliers	0.19	0.18	0.05	0.05	3.48	0.00055
Value Flow->Problem Solving (Simple)	0.23	0.23	0.05	0.05	4.59	0.00001
Value Flow->Support Employees	0.23	0.23	0.04	0.04	5.76	0.00000
Visual Systems->5S	0.37	0.37	0.05	0.05	6.82	0.00000
Visual Systems->Problem Solving (Simple)	0.35	0.35	0.05	0.05	6.84	0.00000

Figure 302 SEM K.1 bootstrapped paths analysis (5000 times, individual sign changes allowed)

SEM K.2 Model Validation

	5S	Communication	Employee Initiatives (Enabled)	Engage Customers	Engage Suppliers	Guiding Coalition	JIT	Journey View	Kaizen Events	Lean/Flow Accounting	Management Knowledge	Outcomes	Planning	Problem Solving (Simple)	Pull/Kanban	Regularity	Standard Work	Statistical Methods	Support Employees	TPM	Value Flow	Visual Systems
5S V086 5S System	1.00																					
COM V050 Mngmnt effective com. process		0.87																				
COM V051 Mngmnt vivid comm. strategy/vision		0.88																				
COM V052 Mngmnt comm. staff role		0.91																				
COM V053 Mngmnt vivid com. steps of change		0.82																				
EE V041 Worker Initiatives			0.84																			
EE V048 Easy for suggestion/improvements			0.89																			
EE V057 Involved all Staff			0.83																			
ENC V101 Engaging customers				1.00																		
ENS V100 Engaging suppliers					1.00																	
GC V077 Guiding coalition supporting						1.00																
JIT V087 Just In Time Manufacture							1.00															
JV V031 JourneyView								1.00														
KAI V090 Kaizen									1.00													
LAC V058 Lean/flow accounting										1.00												
MK V067 Mngmnt understood tools/ methods											0.83											
MK V068 Mngmnt understood as a new culture/ phil											0.86											
MK V105 Mngmnt contin. to learn and participate											0.82											
OC V016 Performance Enhanced												0.86										
OC V040 Sustained Imp.												0.78										
OC V015 Competitive Advantage												0.88										
PL V047 Mngmnt planned well													1.00									
PR V091 5 Whys														0.89								
PR V092 Simple problem solving														0.91								
PUL V094 Pull Systems															0.93							
PUL V095 Kanban															0.91							
REG V072 Small wins prominent																0.81						
REG V078 Program/Structure/Regularity																0.85						
STA V096 Statistical Methods																		1.00				
STW V080 Standard work developed																	1.00					
SU V075 Growth mindset																			0.90			
SU V079 Individual support in adjusting																			0.83			
TPM V089 Total Productive Maintenance																				1.00		
V093 DefiningValue																					0.92	
V097 MappingValue Stream																					0.86	
VS V098 Visual Systems																						1.00

Basic criterion for loading is >0.7. Lower loadings are accepted in exploratory work and removal of slightly lower loadings in PLS SEM is discouraged to support consistency at large.

Figure 303 SEM K.2 indicator loadings in outer model.

	5S	Communication	Employee Initiatives (Enabled)	Engage Customers	Engage Suppliers	Guiding Coalition	JIT	Journey View	Kaizen Events	Lean/Flow Accounting	Management Knowledge	Outcomes	Planning	Problem Solving (Simple)	Pull/Kanban	Regularity	Standard Work	Statistical Methods	Support Employees	TPM	Value Flow	Visual Systems
5S V086 5S System	1.00	0.13	0.34	0.03	0.15	0.18	0.42	0.26	0.42	-0.09	0.20	0.23	0.00	0.44	0.30	0.25	0.32	0.12	0.18	0.46	0.16	0.42
COM V050 Mngmnt effective com. process	0.10	0.87	0.66	0.53	0.52	0.30	0.32	0.40	0.15	0.40	0.63	0.55	0.52	0.36	0.28	0.47	0.34	0.29	0.60	0.33	0.30	0.34
COM V051 Mngmnt vivid comm. strategy/vision	0.08	0.88	0.60	0.55	0.48	0.24	0.34	0.33	0.21	0.40	0.58	0.54	0.43	0.29	0.29	0.39	0.40	0.34	0.58	0.40	0.35	0.33
COM V052 Mngmnt comm. staff role	0.11	0.91	0.65	0.59	0.57	0.40	0.36	0.31	0.20	0.43	0.63	0.53	0.56	0.38	0.32	0.50	0.41	0.33	0.60	0.44	0.36	0.30
COM V053 Mngmnt vivid com. steps of change	0.15	0.82	0.65	0.50	0.40	0.42	0.29	0.36	0.26	0.37	0.64	0.50	0.55	0.37	0.31	0.57	0.48	0.32	0.55	0.46	0.35	0.31
EE V041 Worker Initiatives	0.34	0.55	0.84	0.34	0.30	0.38	0.27	0.48	0.26	0.26	0.60	0.56	0.39	0.56	0.29	0.58	0.57	0.27	0.64	0.35	0.41	0.47
EE V048 Easy for suggestion/improvements	0.33	0.66	0.89	0.33	0.35	0.39	0.35	0.47	0.18	0.31	0.64	0.55	0.62	0.44	0.34	0.53	0.49	0.14	0.64	0.44	0.21	0.41
EE V057 Involved all Staff	0.20	0.67	0.83	0.34	0.37	0.38	0.33	0.49	0.26	0.39	0.58	0.51	0.46	0.49	0.24	0.55	0.46	0.19	0.59	0.41	0.22	0.43
ENC V101 Engaging customers	0.03	0.63	0.39	1.00	0.67	0.14	0.28	0.19	0.14	0.26	0.43	0.40	0.37	0.31	0.32	0.32	0.36	0.28	0.45	0.26	0.45	0.29
ENS V100 Engaging suppliers	0.15	0.57	0.40	0.67	1.00	0.20	0.45	0.17	0.08	0.32	0.41	0.43	0.30	0.25	0.51	0.32	0.42	0.36	0.38	0.37	0.31	0.41
GC V077 Guiding coalition supporting	0.18	0.39	0.45	0.14	0.20	1.00	0.14	0.26	0.17	0.11	0.43	0.28	0.36	0.40	0.20	0.62	0.55	0.24	0.50	0.24	0.34	0.39
JIT V087 Just In Time Manufacture	0.42	0.38	0.37	0.28	0.45	0.14	1.00	0.32	0.47	0.21	0.38	0.46	0.35	0.44	0.73	0.32	0.37	0.25	0.29	0.55	0.34	0.34
JV V031 JourneyView	0.26	0.40	0.56	0.19	0.17	0.26	0.32	1.00	0.23	0.07	0.54	0.45	0.33	0.48	0.17	0.53	0.42	0.17	0.43	0.26	0.20	0.44
KAI V090 Kaizen	0.42	0.23	0.27	0.14	0.08	0.17	0.47	0.23	1.00	0.10	0.23	0.28	0.11	0.52	0.42	0.28	0.30	0.24	0.22	0.51	0.40	0.19
LAC V058 Lean/flow accounting	-0.09	0.46	0.37	0.26	0.32	0.11	0.21	0.07	0.10	1.00	0.39	0.38	0.33	0.08	0.33	0.15	0.30	0.24	0.26	0.21	0.21	0.07
MK V067 Mngmnt understood tools/ methods	0.14	0.53	0.52	0.30	0.32	0.23	0.30	0.39	0.17	0.33	0.83	0.37	0.45	0.30	0.28	0.44	0.38	0.26	0.44	0.35	0.18	0.32
MK V068 Mngmnt understood as a new culture/ phil	0.17	0.61	0.62	0.42	0.30	0.37	0.29	0.48	0.27	0.30	0.86	0.42	0.50	0.45	0.23	0.59	0.46	0.26	0.58	0.37	0.29	0.42
MK V105 Mngmnt contin. to learn and participate	0.18	0.62	0.63	0.35	0.39	0.45	0.35	0.48	0.13	0.35	0.82	0.48	0.48	0.50	0.36	0.56	0.51	0.43	0.63	0.39	0.36	0.55
OC V016 Performance Enhanced	0.17	0.46	0.46	0.31	0.38	0.20	0.45	0.30	0.32	0.34	0.39	0.86	0.26	0.33	0.54	0.35	0.41	0.35	0.47	0.36	0.39	0.42
OC V040 Sustained Imp.	0.25	0.60	0.66	0.34	0.34	0.30	0.30	0.55	0.15	0.30	0.54	0.78	0.37	0.42	0.32	0.47	0.52	0.25	0.58	0.37	0.35	0.39
OC V015 Competitive Advantage	0.15	0.46	0.47	0.37	0.38	0.19	0.42	0.28	0.24	0.34	0.36	0.88	0.30	0.28	0.53	0.29	0.48	0.21	0.36	0.37	0.39	0.38
PL V047 Mngmnt planned well	0.00	0.59	0.57	0.37	0.30	0.36	0.35	0.33	0.11	0.33	0.57	0.37	1.00	0.33	0.31	0.49	0.36	0.26	0.47	0.28	0.25	0.22
PR V091 5 Whys	0.39	0.32	0.44	0.27	0.21	0.31	0.44	0.40	0.56	0.08	0.43	0.35	0.25	0.89	0.42	0.47	0.42	0.25	0.34	0.52	0.45	0.44
PR V092 Simple problem solving	0.40	0.40	0.60	0.28	0.23	0.41	0.35	0.45	0.38	0.05	0.48	0.38	0.34	0.91	0.29	0.57	0.44	0.30	0.52	0.40	0.49	0.48
PUL V094 Pull Systems	0.23	0.35	0.33	0.33	0.47	0.22	0.67	0.19	0.40	0.29	0.32	0.53	0.31	0.42	0.93	0.26	0.45	0.35	0.30	0.44	0.60	0.46
PUL V095 Kanban	0.32	0.28	0.29	0.25	0.48	0.15	0.68	0.11	0.37	0.33	0.33	0.49	0.26	0.29	0.91	0.17	0.36	0.31	0.27	0.40	0.31	0.32
REG V072 Small wins prominent	0.23	0.42	0.56	0.25	0.26	0.39	0.24	0.47	0.31	0.05	0.48	0.35	0.22	0.53	0.12	0.81	0.42	0.30	0.53	0.36	0.32	0.48
REG V078 Program/Structure/Regularity	0.18	0.50	0.52	0.28	0.27	0.62	0.29	0.41	0.17	0.19	0.57	0.38	0.57	0.43	0.26	0.85	0.62	0.35	0.51	0.32	0.39	0.37
STA V096 Statistical Methods	0.12	0.37	0.23	0.28	0.36	0.24	0.25	0.17	0.24	0.24	0.39	0.32	0.26	0.31	0.36	0.39	0.40	1.00	0.41	0.31	0.36	0.18
STW V080 Standard work developed	0.32	0.47	0.59	0.36	0.42	0.55	0.37	0.42	0.30	0.30	0.55	0.56	0.36	0.48	0.44	0.63	1.00	0.40	0.52	0.42	0.40	0.48
SU V075 Growth mindset	0.20	0.62	0.69	0.36	0.30	0.41	0.27	0.38	0.21	0.27	0.69	0.54	0.43	0.42	0.28	0.57	0.44	0.39	0.90	0.30	0.44	0.46
SU V079 Individual support in adjusting	0.10	0.53	0.56	0.44	0.36	0.45	0.22	0.37	0.16	0.18	0.44	0.43	0.38	0.42	0.26	0.51	0.46	0.33	0.83	0.15	0.35	0.38
TPM V089 Total Productive Maintenance	0.46	0.46	0.47	0.26	0.37	0.24	0.55	0.26	0.51	0.21	0.45	0.44	0.28	0.51	0.46	0.41	0.42	0.31	0.27	1.00	0.30	0.42
V093 DefiningValue	0.15	0.37	0.30	0.41	0.32	0.30	0.36	0.25	0.42	0.21	0.34	0.50	0.22	0.50	0.53	0.37	0.42	0.35	0.41	0.36	0.92	0.34
V097 MappingValue Stream	0.14	0.32	0.28	0.40	0.24	0.31	0.23	0.10	0.28	0.16	0.26	0.28	0.23	0.42	0.35	0.41	0.28	0.30	0.42	0.16	0.86	0.42
VS V098 Visual Systems	0.42	0.37	0.51	0.29	0.41	0.39	0.34	0.44	0.19	0.07	0.53	0.48	0.22	0.51	0.43	0.51	0.48	0.18	0.49	0.42	0.42	1.00

Variables must load their consruct higher than any other construct. Values > 0.6 highlighted

Figure 304 SEM K.2 indicator cross loadings

Negative relationships and p>0.01 highlighted	Original Sample (β)	Sample Mean	Standard Deviation	Standard Error	T Statistics	p -value (Significance)
5S->Employee Initiatives (Enabled)	0.14	0.15	0.05	0.05	2.77	0.00635
5S->Visual Systems	0.27	0.27	0.08	0.08	3.44	0.00076
Communication->Engage Customers	0.36	0.36	0.07	0.07	5.06	0.00000
Communication->Engage Suppliers	0.44	0.44	0.06	0.06	7.95	0.00000
Communication->Support Employees	0.30	0.29	0.08	0.08	3.85	0.00018
Employee Initiatives (Enabled)->Outcomes	0.46	0.46	0.09	0.09	5.34	0.00000
Engage Customers->Value Flow	0.30	0.29	0.07	0.07	4.25	0.00004
Engage Suppliers->Engage Customers	0.46	0.46	0.08	0.08	5.97	0.00000
Guiding Coalition->Regularity	0.29	0.29	0.05	0.05	5.35	0.00000
JIT->Pull/Kanban	0.73	0.73	0.05	0.05	14.87	0.00000
Journey View->Employee Initiatives (Enabled)	0.17	0.17	0.05	0.05	3.21	0.00161
Journey View->Outcomes	0.18	0.18	0.07	0.07	2.54	0.01216
Kaizen Events->5S	0.25	0.25	0.10	0.10	2.53	0.01235
Kaizen Events->Problem Solving (Simple)	0.47	0.47	0.07	0.07	6.71	0.00000
Kaizen Events->TPM	0.36	0.36	0.09	0.09	3.98	0.00011
Kaizen Events->Visual Systems	-0.22	-0.23	0.08	0.08	2.81	0.00559
Lean/Flow Accounting->Communication	0.18	0.18	0.06	0.06	3.13	0.00210
Lean/Flow Accounting->Employee Initiatives (Enabled)	0.18	0.18	0.05	0.05	3.55	0.00053
Management Knowledge->Communication	0.50	0.50	0.08	0.08	6.47	0.00000
Management Knowledge->Employee Initiatives (Enabled)	0.19	0.19	0.07	0.07	2.70	0.00779
Management Knowledge->Guiding Coalition	0.35	0.36	0.10	0.10	3.52	0.00059
Management Knowledge->JIT	0.27	0.27	0.09	0.09	2.96	0.00359
Management Knowledge->Journey View	0.31	0.31	0.08	0.08	4.05	0.00008
Management Knowledge->Lean/Flow Accounting	0.31	0.31	0.07	0.07	4.28	0.00003
Management Knowledge->Planning	0.57	0.57	0.07	0.07	8.53	0.00000
Management Knowledge->Regularity	0.22	0.22	0.07	0.07	2.99	0.00324
Management Knowledge->Statistical Methods	0.30	0.30	0.07	0.07	4.17	0.00005
Management Knowledge->Support Employees	0.25	0.25	0.09	0.09	2.86	0.00484
Management Knowledge->TPM	0.29	0.29	0.06	0.06	4.59	0.00001
Management Knowledge->Visual Systems	0.31	0.31	0.07	0.07	4.56	0.00001
Planning->Communication	0.25	0.24	0.07	0.07	3.69	0.00032
Planning->JIT	0.20	0.20	0.09	0.09	2.16	0.03278
Planning->Regularity	0.12	0.13	0.06	0.06	1.97	0.05132
Problem Solving (Simple)->Employee Initiatives (Enabled)	0.14	0.13	0.06	0.06	2.20	0.02943
Problem Solving (Simple)->Journey View	0.20	0.19	0.08	0.08	2.55	0.01186
Problem Solving (Simple)->Outcomes	-0.17	-0.17	0.09	0.09	2.00	0.04736
Problem Solving (Simple)->Visual Systems	0.26	0.27	0.08	0.08	3.39	0.00091
Pull/Kanban->Engage Suppliers	0.36	0.36	0.06	0.06	5.82	0.00000
Pull/Kanban->Kaizen Events	0.29	0.29	0.07	0.07	3.86	0.00017
Pull/Kanban->Lean/Flow Accounting	0.22	0.22	0.08	0.08	2.82	0.00555
Pull/Kanban->Outcomes	0.34	0.34	0.07	0.07	4.77	0.00000
Pull/Kanban->Statistical Methods	0.25	0.25	0.07	0.07	3.53	0.00056
Pull/Kanban->TPM	0.20	0.20	0.08	0.08	2.41	0.01712
Pull/Kanban->Value Flow	0.35	0.36	0.07	0.07	5.36	0.00000
Pull/Kanban->Visual Systems	0.23	0.23	0.07	0.07	3.37	0.00095
Regularity->Journey View	0.22	0.22	0.09	0.09	2.50	0.01347
Regularity->Support Employees	0.23	0.23	0.08	0.08	2.95	0.00371
Standard Work->Regularity	0.19	0.19	0.07	0.07	2.61	0.00994
Statistical Methods->Problem Solving (Simple)	0.20	0.20	0.07	0.07	2.70	0.00783
Statistical Methods->Regularity	0.10	0.10	0.05	0.05	1.93	0.05501
Statistical Methods->Value Flow	0.15	0.15	0.07	0.07	2.14	0.03399
Support Employees->Employee Initiatives (Enabled)	0.39	0.39	0.06	0.06	6.86	0.00000
TPM->5S	0.33	0.33	0.09	0.09	3.51	0.00059
TPM->Standard Work	0.27	0.27	0.08	0.08	3.62	0.00040
Value Flow->Guiding Coalition	0.22	0.22	0.07	0.07	3.08	0.00250
Value Flow->Kaizen Events	0.26	0.26	0.08	0.08	3.23	0.00151
Value Flow->Outcomes	0.18	0.18	0.08	0.08	2.34	0.02080
Value Flow->Support Employees	0.16	0.16	0.06	0.06	2.54	0.01203
Visual Systems->Regularity	0.14	0.14	0.07	0.07	1.95	0.05329
Visual Systems->Standard Work	0.36	0.36	0.07	0.07	4.88	0.00000

Figure 305 SEM K.2 bootstrapped paths analysis (5000 times, individual sign changes allowed).

SEM K.3 Model Validation

	5S	Communication	Employee Initiatives (Enabled)	Engage Customers	Engage Suppliers	Guiding Coalition	JIT	Journey View	Kaizen Events	Lean/Flow Accounting	Management Knowledge	Outcomes	Planning	Problem Solving (Simple)	Pull/Kanban	Regularity	Standard Work	Statistical Methods	Support Employees	TPM	Value Flow	Visual Systems
5S V086 5S System	1.00																					
COM V050 Mngmnt effective com. proces		0.80																				
COM V051 Mngmnt vivid comm. strategy/		0.88																				
COM V052 Mngmnt comm. staff role		0.89																				
COM V053 Mngmnt vivid com. steps of ch		0.81																				
EE V041 Worker Initiatives			0.84																			
EE V048 Easy for suggestion/improvement			0.78																			
EE V057 Involved all Staff			0.87																			
ENC V101 Engaging customers				1.00																		
ENS V100 Engaging suppliers					1.00																	
GC V077 Guiding coalition supporting						1.00																
JIT V087 Just In Time Manufacture							1.00															
JV V031 JourneyView								1.00														
KAI V090 Kaizen									1.00													
LAC V058 Lean/flow accounting										1.00												
MK V067 Mngmnt understood tools/ metho											0.87											
MK V068 Mngmnt understood as a new cu											0.81											
MK V105 Mngmnt contin. to learn and par											0.80											
OC V016 Performance Enhanced												0.93										
OC V040 Sustained Imp.												0.83										
OC V015 Competitive Advantage												0.85										
PL V047 Mngmnt planned well													1.00									
PR V091 5 Whys														0.88								
PR V092 Simple problem solving														0.91								
PUL V094 Pull Systems															0.92							
PUL V095 Kanban															0.77							
REG V072 Small wins prominent																0.73						
REG V078 Program/Structure/Regularity																0.87						
STA V096 Statistical Methods																		1.00				
STW V080 Standard work developed																	1.00					
SU V075 Growth mindset																			0.84			
SU V079 Individual support in adjusting																			0.86			
TPM V089 Total Productive Maintenance																				1.00		
V093 DefiningValue																					0.76	
V097 MappingValue Stream																					0.92	
VS V098 Visual Systems																						1.00

Basic criterion for loading is >0.7. Lower loadings are accepted in exploratory work and removal of slightly lower loadings in PLS SEM is discouraged to support consistency at large.

Figure 306 SEM K.3 indicator loadings in outer model.

	5S	Communication	Employee Initiatives (Enabled)	Engage Customers	Engage Suppliers	Guiding Coalition	JIT	Journey View	Kaizen Events	Lean/Flow Accounting	Management Knowledge	Outcomes	Planning	Problem Solving (Simple)	Pull/Kanban	Regularity	Standard Work	Statistical Methods	Support Employees	TPM	Value Flow	Visual Systems
5S V086 5S System	1.00	0.44	0.45	0.05	0.22	0.25	0.32	0.38	0.45	0.12	0.33	0.16	0.35	0.41	0.40	0.31	0.40	0.18	0.31	0.46	0.29	0.58
COM V050 Mngmnt effective com. proces	0.28	0.80	0.63	0.32	0.35	0.36	0.29	0.14	0.17	0.25	0.40	0.63	0.66	0.20	0.24	0.37	0.32	-0.02	0.42	-0.02	0.33	0.46
COM V051 Mngmnt vivid comm. strategy/	0.35	0.88	0.57	0.18	0.14	0.29	0.18	0.31	0.20	0.24	0.47	0.41	0.51	0.26	0.23	0.34	0.27	-0.20	0.19	0.12	0.32	0.42
COM V052 Mngmnt comm. staff role	0.47	0.89	0.62	0.32	0.26	0.37	0.25	0.28	0.28	0.41	0.49	0.44	0.62	0.40	0.29	0.51	0.29	-0.01	0.33	0.36	0.38	0.49
COM V053 Mngmnt vivid com. steps of ch	0.39	0.81	0.44	0.29	0.24	0.38	0.18	0.02	0.24	0.13	0.24	0.37	0.64	0.16	0.27	0.46	0.17	-0.02	0.33	0.13	0.35	0.36
EE V041 Worker Initiatives	0.28	0.46	0.84	0.40	0.34	0.33	0.24	0.39	0.23	0.34	0.60	0.60	0.37	0.52	0.17	0.45	0.49	0.00	0.49	0.22	0.33	0.67
EE V048 Easy for suggestion/improvement	0.41	0.62	0.78	0.24	0.31	0.50	0.13	0.27	0.22	0.30	0.57	0.62	0.57	0.29	0.35	0.44	0.28	-0.04	0.50	0.01	0.13	0.29
EE V057 Involved all Staff	0.42	0.59	0.87	0.41	0.38	0.41	0.26	0.54	0.30	0.46	0.61	0.62	0.45	0.47	0.22	0.55	0.40	-0.04	0.59	0.24	0.39	0.58
ENC V101 Engaging customers	0.05	0.33	0.42	1.00	0.57	0.35	0.12	0.15	0.00	0.31	0.34	0.49	0.36	0.22	0.14	0.35	0.41	0.24	0.48	0.11	0.52	0.42
ENS V100 Engaging suppliers	0.22	0.30	0.41	0.57	1.00	0.27	0.48	0.17	0.05	0.43	0.33	0.34	0.39	0.22	0.29	0.17	0.29	0.30	0.32	0.13	0.42	0.39
GC V077 Guiding coalition supporting	0.25	0.42	0.50	0.35	0.27	1.00	0.08	0.20	0.12	0.19	0.48	0.46	0.39	0.27	0.29	0.54	0.35	0.15	0.49	0.18	0.23	0.34
JIT V087 Just In Time Manufacture	0.32	0.27	0.26	0.12	0.48	0.08	1.00	0.24	0.36	0.22	0.27	0.25	0.30	0.06	0.37	0.05	0.19	0.11	0.07	0.34	0.32	0.37
JV V031 JourneyView	0.38	0.22	0.49	0.15	0.17	0.20	0.24	1.00	0.09	0.24	0.42	0.38	0.00	0.35	0.10	0.26	0.32	0.13	0.28	0.12	0.22	0.41
KAI V090 Kaizen	0.45	0.26	0.30	0.00	0.05	0.12	0.36	0.09	1.00	0.16	0.21	0.18	0.18	0.34	0.56	0.31	0.16	0.03	0.31	0.49	0.27	0.32
LAC V058 Lean/flow accounting	0.12	0.31	0.45	0.31	0.43	0.19	0.22	0.24	0.16	1.00	0.34	0.34	0.25	0.35	0.25	0.24	0.25	0.13	0.21	0.30	0.24	0.38
MK V067 Mngmnt understood tools/ metho	0.29	0.35	0.58	0.23	0.30	0.49	0.25	0.42	0.13	0.43	0.87	0.47	0.35	0.41	0.31	0.21	0.26	0.08	0.37	0.16	0.22	0.43
MK V068 Mngmnt understood as a new cu	0.27	0.31	0.49	0.27	0.24	0.26	0.18	0.29	0.07	0.31	0.81	0.36	0.29	0.41	0.14	0.30	0.43	-0.16	0.38	0.15	0.28	0.44
MK V105 Mngmnt contin. to learn and par	0.25	0.51	0.69	0.34	0.26	0.41	0.23	0.32	0.31	0.11	0.80	0.55	0.37	0.30	0.34	0.49	0.41	-0.08	0.51	0.15	0.31	0.45
OC V016 Performance Enhanced	0.13	0.50	0.68	0.43	0.34	0.43	0.30	0.33	0.19	0.36	0.48	0.93	0.44	0.22	0.29	0.52	0.40	-0.06	0.52	-0.04	0.38	0.45
OC V040 Sustained Imp.	0.16	0.52	0.70	0.56	0.31	0.47	0.11	0.37	0.13	0.26	0.57	0.83	0.37	0.28	0.28	0.47	0.50	-0.01	0.52	0.06	0.36	0.43
OC V015 Competitive Advantage	0.12	0.41	0.51	0.25	0.22	0.27	0.27	0.29	0.16	0.27	0.39	0.85	0.44	0.17	0.16	0.30	0.36	0.04	0.29	-0.02	0.21	0.37
PL V047 Mngmnt planned well	0.35	0.72	0.56	0.36	0.39	0.39	0.30	0.00	0.18	0.25	0.41	0.48	1.00	0.30	0.21	0.35	0.13	0.00	0.35	0.14	0.27	0.41
PR V091 5 Whys	0.46	0.31	0.45	0.10	0.13	0.19	0.01	0.21	0.41	0.38	0.29	0.17	0.21	0.88	0.27	0.31	0.39	0.24	0.38	0.43	0.36	0.52
PR V092 Simple problem solving	0.28	0.24	0.47	0.29	0.25	0.28	0.09	0.41	0.21	0.26	0.50	0.29	0.31	0.91	0.07	0.31	0.35	0.20	0.46	0.23	0.41	0.56
PUL V094 Pull Systems	0.27	0.30	0.28	0.24	0.25	0.31	0.30	0.08	0.51	0.25	0.32	0.37	0.24	0.15	0.92	0.19	0.16	0.09	0.35	0.23	0.47	0.19
PUL V095 Kanban	0.48	0.19	0.22	-0.07	0.24	0.14	0.36	0.10	0.43	0.18	0.23	0.05	0.08	0.17	0.77	0.08	0.09	0.31	0.21	0.43	0.26	0.22
REG V072 Small wins prominent	0.06	0.40	0.47	0.32	0.16	0.24	0.14	0.22	0.15	0.19	0.34	0.41	0.25	0.21	-0.01	0.73	0.24	0.00	0.45	0.09	0.11	0.21
REG V078 Program/Structure/Regularity	0.38	0.41	0.47	0.26	0.13	0.59	-0.03	0.20	0.33	0.20	0.32	0.41	0.31	0.33	0.25	0.87	0.32	0.19	0.59	0.19	0.33	0.43
STA V096 Statistical Methods	0.18	-0.07	-0.03	0.24	0.30	0.15	0.11	0.13	0.03	0.13	-0.05	-0.01	0.00	0.24	0.20	0.13	0.11	1.00	0.24	0.21	0.33	0.12
STW V080 Standard work developed	0.40	0.31	0.47	0.41	0.29	0.35	0.19	0.32	0.16	0.25	0.43	0.49	0.13	0.41	0.15	0.36	1.00	0.11	0.44	0.24	0.37	0.66
SU V075 Growth mindset	0.31	0.33	0.59	0.34	0.20	0.34	0.09	0.34	0.25	0.18	0.60	0.42	0.24	0.50	0.34	0.40	0.45	0.10	0.84	0.21	0.35	0.41
SU V079 Individual support in adjusting	0.23	0.31	0.50	0.47	0.33	0.49	0.04	0.15	0.28	0.18	0.28	0.46	0.36	0.31	0.25	0.70	0.30	0.30	0.86	0.09	0.37	0.28
TPM V089 Total Productive Maintenance	0.46	0.18	0.19	0.11	0.13	0.18	0.34	0.12	0.49	0.30	0.19	0.00	0.14	0.36	0.35	0.18	0.24	0.21	0.17	1.00	0.16	0.39
V093 DefiningValue	0.14	0.29	0.18	0.28	0.20	0.10	0.26	0.18	0.26	0.04	0.22	0.31	0.16	0.31	0.29	0.28	0.20	0.21	0.36	-0.05	0.76	0.33
V097 MappingValue Stream	0.31	0.39	0.37	0.54	0.46	0.25	0.28	0.19	0.21	0.31	0.32	0.32	0.27	0.41	0.46	0.23	0.39	0.32	0.36	0.25	0.92	0.58
VS V098 Visual Systems	0.58	0.52	0.62	0.42	0.39	0.34	0.37	0.41	0.32	0.38	0.53	0.48	0.41	0.61	0.23	0.41	0.66	0.12	0.41	0.39	0.57	1.00

Variables must load their consruct higher than any other consti Values > 0.6 highlighted

Figure 307 SEM K.3 indicator cross loadings

Negative relationships and p>0.01 highlighted	Original Sample (β)	Sample Mean	Standard Deviation	Standard Error	T Statistics	p -value (Significance)
Kaizen Events->Problem Solving (Simple)	0.15	0.16	0.08	0.08	1.94	0.05555
JIT->Journey View	0.19	0.19	0.09	0.09	2.04	0.04437
JIT->Engage Customers	-0.19	-0.20	0.09	0.09	2.05	0.04381
Value Flow->Support Employees	0.18	0.19	0.08	0.08	2.11	0.03836
Management Knowledge->Problem Solving (Simple)	0.20	0.20	0.09	0.09	2.14	0.03569
Management Knowledge->Engage Suppliers	0.21	0.21	0.10	0.10	2.18	0.03216
Management Knowledge->Lean/Flow Accounting	0.23	0.23	0.10	0.10	2.36	0.02097
Management Knowledge->Pull/Kanban	0.25	0.26	0.10	0.10	2.45	0.01645
Guiding Coalition->Planning	0.25	0.24	0.10	0.10	2.52	0.01388
Pull/Kanban->Outcomes	0.19	0.20	0.08	0.08	2.54	0.01307
Value Flow->Employee Initiatives (Enabled)	-0.17	-0.16	0.07	0.07	2.55	0.01272
Statistical Methods->Problem Solving (Simple)	0.20	0.20	0.08	0.08	2.56	0.01245
Problem Solving (Simple)->Support Employees	0.21	0.21	0.08	0.08	2.59	0.01156
Kaizen Events->TPM	0.36	0.36	0.14	0.14	2.63	0.01034
Problem Solving (Simple)->Outcomes	-0.19	-0.19	0.07	0.07	2.73	0.00792
Management Knowledge->Communication	0.22	0.23	0.08	0.08	2.76	0.00711
Communication->Regularity	0.33	0.33	0.12	0.12	2.79	0.00668
Management Knowledge->Planning	0.29	0.30	0.10	0.10	2.83	0.00597
Journey View->Outcomes	0.21	0.21	0.07	0.07	2.83	0.00590
Visual Systems->Employee Initiatives (Enabled)	0.24	0.25	0.09	0.09	2.83	0.00584
5S->TPM	0.30	0.30	0.10	0.10	2.90	0.00481
Lean/Flow Accounting->Visual Systems	0.26	0.25	0.09	0.09	2.93	0.00447
JIT->Pull/Kanban	0.31	0.30	0.10	0.10	2.98	0.00381
Regularity->Engage Customers	0.25	0.25	0.08	0.08	3.12	0.00254
Value Flow->Statistical Methods	0.33	0.33	0.10	0.10	3.14	0.00236
Kaizen Events->5S	0.29	0.29	0.09	0.09	3.31	0.00141
Engage Suppliers->Lean/Flow Accounting	0.35	0.35	0.10	0.10	3.42	0.00098
Regularity->Kaizen Events	0.30	0.30	0.08	0.08	3.59	0.00057
Planning->JIT	0.30	0.30	0.08	0.08	3.61	0.00054
Guiding Coalition->Regularity	0.41	0.41	0.11	0.11	3.72	0.00037
JIT->Kaizen Events	0.34	0.34	0.09	0.09	3.91	0.00019
Planning->Outcomes	0.29	0.29	0.07	0.07	3.93	0.00018
JIT->Engage Suppliers	0.42	0.42	0.11	0.11	3.97	0.00016
Management Knowledge->Employee Initiatives (Enabled)	0.31	0.31	0.08	0.08	4.03	0.00013
5S->Outcomes	-0.40	-0.40	0.10	0.10	4.07	0.00011
Standard Work->Outcomes	0.35	0.33	0.08	0.08	4.09	0.00010
Support Employees->Employee Initiatives (Enabled)	0.32	0.31	0.08	0.08	4.14	0.00009
Visual Systems->Problem Solving (Simple)	0.43	0.43	0.10	0.10	4.37	0.00004
Planning->Journey View	-0.43	-0.44	0.10	0.10	4.38	0.00004
Communication->Employee Initiatives (Enabled)	0.34	0.35	0.07	0.07	4.60	0.00002
Pull/Kanban->Value Flow	0.39	0.39	0.08	0.08	4.61	0.00002
Visual Systems->5S	0.48	0.49	0.10	0.10	4.71	0.00001
Management Knowledge->Guiding Coalition	0.48	0.47	0.10	0.10	4.91	0.00000
Value Flow->Visual Systems	0.51	0.51	0.09	0.09	5.88	0.00000
Engage Suppliers->Engage Customers	0.62	0.62	0.10	0.10	6.02	0.00000
Engage Customers->Value Flow	0.46	0.46	0.07	0.07	6.88	0.00000
Employee Initiatives (Enabled)->Outcomes	0.52	0.52	0.08	0.08	6.91	0.00000
Employee Initiatives (Enabled)->Journey View	0.68	0.68	0.09	0.09	7.27	0.00000
Regularity->Support Employees	0.53	0.52	0.07	0.07	7.31	0.00000
Visual Systems->Standard Work	0.66	0.66	0.07	0.07	9.40	0.00000
Planning->Communication	0.63	0.63	0.06	0.06	9.90	0.00000

Figure 308 SEM K.3 bootstrapped paths analysis (5000 times, individual sign changes allowed)

SEM K.4 Model Validation

	5S	Communication	Employee Initiatives	Engage Customers	Engage Suppliers	Guiding Coalition	Information Systems	JIT	Journey View	Kaizen Events	Lean/Flow Accounting	Management Knowledge	Outcomes	Planning	Problem Solving (Simple)	Pull/Kanban	Regularity	Resource	Satistical Methods	Standard Work	Support Employee	TPM	Value Flow	Visual Systems
5S V086 5S System	1.00																							
COM V051 Mngmnt vivid comm. strategy/		0.92																						
COM V052 Mngmnt comm. staff role		0.95																						
COM V053 Mngmnt vivid com. steps of ch		0.90																						
EE V041 Worker Initiatives			0.88																					
EE V048 Easy for suggestion/improvement			0.84																					
EE V057 Involved all Staff			0.90																					
ENC V101 Engaging customers				1.00																				
ENS V100 Engaging suppliers					1.00																			
GC V077 Guiding coalition supporting						1.00																		
ITS V085 Information Systems							1.00																	
JIT V087 Just In Time Manufacture								1.00																
JV V031 JourneyView									1.00															
KAI V090 Kaizen										1.00														
LAC V058 Lean/flow accounting											1.00													
MK V067 Mngmnt understood tools/ metho												0.84												
MK V068 Mngmnt understood as a new cu												0.85												
MK V105 Mngmnt contin. to learn and par												0.82												
OC V016 Performance Enhanced													0.95											
OC V040 Sustained Imp.													0.88											
OC V015 Competitive Advantage													0.89											
PL V047 Mngmnt planned well														1.00										
PR V092 Simple problem solving															1.00									
PUL V094 Pull Systems																0.90								
PUL V095 Kanban																0.93								
REG V078 Program/Structure/Regularity																	1.00							
RES V062 Staff Capability																		0.81						
RES V063 Technology Capability																		0.91						
STA V096 Statistical Methods																			1.00					
STW V080 Standard work developed																				1.00				
SU V075 Growth mindset																					0.86			
SU V079 Individual support in adjusting																					0.87			
TPM V089 Total Productive Maintenance																						1.00		
V059 Flow focus																							0.61	
V093 DefiningValue																							0.78	
V097 MappingValue Stream																							0.80	
VS V098 Visual Systems																								1.00

Basic criterion for loading is >0.7. Lower loadings are accepted in exploratory work and removal of slightly lower loadings in PLS SEM is discouraged to support consistency at large.

Figure 309 SEM K.4 indicator loadings in outer model.

	5S	Communication	Employee Initiatives	Engage Customers	Engage Suppliers	Guiding Coalition	Information Systems	JIT	Journey View	Kaizen Events	Lean/Flow Accounting	Management Knowledge	Outcomes	Planning	Problem Solving (Simple)	Pull/Kanban	Regularity	Resource	Satistical Methods	Standard Work	Support Employees	TPM	Value Flow	Visual Systems
5S V086 5S System	1.00	0.10	0.35	-0.04	0.16	0.41	0.19	0.24	0.08	0.42	0.08	0.27	0.11	0.19	0.34	0.25	0.30	0.08	0.30	0.34	0.29	0.49	0.24	0.52
COM V051 Mngmnt vivid comm. strategy/	-0.08	0.92	0.59	0.41	0.34	0.15	0.15	0.32	0.31	0.31	0.35	0.56	0.49	0.55	0.14	0.34	0.29	0.29	0.06	0.26	0.49	0.25	0.52	0.17
COM V052 Mngmnt comm. staff role	0.14	0.95	0.65	0.40	0.34	0.20	0.15	0.37	0.33	0.36	0.32	0.59	0.53	0.62	0.29	0.37	0.43	0.28	0.11	0.27	0.62	0.39	0.55	0.27
COM V053 Mngmnt vivid com. steps of ch	0.18	0.90	0.60	0.40	0.42	0.27	0.15	0.37	0.23	0.40	0.23	0.46	0.46	0.64	0.16	0.28	0.58	0.38	0.14	0.23	0.60	0.39	0.54	0.18
EE V041 Worker Initiatives	0.23	0.61	0.88	0.29	0.34	0.50	0.16	0.34	0.58	0.20	0.41	0.67	0.62	0.54	0.42	0.24	0.31	0.31	0.07	0.41	0.62	0.40	0.51	0.48
EE V048 Easy for suggestion/improvement	0.34	0.62	0.84	0.30	0.40	0.45	0.23	0.49	0.34	0.21	0.29	0.67	0.57	0.80	0.37	0.28	0.43	0.41	0.08	0.42	0.60	0.26	0.45	0.34
EE V057 Involved all Staff	0.34	0.51	0.90	0.28	0.33	0.40	0.22	0.33	0.51	0.19	0.45	0.63	0.52	0.58	0.41	0.14	0.26	0.33	0.08	0.45	0.59	0.32	0.37	0.39
ENC V101 Engaging customers	-0.04	0.44	0.33	1.00	0.75	0.11	0.40	0.51	0.19	0.00	0.34	0.42	0.44	0.38	0.21	0.34	0.23	0.58	0.24	0.21	0.43	0.24	0.34	0.21
ENS V100 Engaging suppliers	0.16	0.40	0.41	0.75	1.00	0.25	0.41	0.61	0.32	0.05	0.45	0.48	0.41	0.44	0.33	0.45	0.28	0.54	0.32	0.27	0.44	0.36	0.38	0.40
GC V077 Guiding coalition supporting	0.41	0.23	0.52	0.11	0.25	1.00	0.30	0.22	0.28	0.21	0.12	0.39	0.28	0.38	0.34	0.06	0.37	0.13	0.32	0.34	0.40	0.31	0.27	0.21
ITS V085 Information Systems	0.19	0.16	0.23	0.40	0.41	0.30	1.00	0.33	0.04	0.20	0.49	0.30	0.10	0.28	0.16	0.26	0.10	0.26	0.34	0.22	0.32	0.26	0.25	0.01
JIT V087 Just In Time Manufacture	0.24	0.39	0.44	0.51	0.61	0.22	0.33	1.00	0.27	0.22	0.33	0.49	0.46	0.44	0.49	0.67	0.27	0.53	0.36	0.38	0.49	0.39	0.61	0.38
JV V031 JourneyView	0.08	0.31	0.55	0.19	0.32	0.28	0.04	0.27	1.00	0.05	0.25	0.53	0.43	0.25	0.50	0.15	0.14	0.33	0.14	0.36	0.30	0.27	0.32	0.47
KAI V090 Kaizen	0.42	0.39	0.23	0.00	0.05	0.21	0.20	0.22	0.05	1.00	0.00	0.20	0.11	0.17	0.23	0.36	0.38	-0.08	0.16	0.29	0.37	0.42	0.48	0.24
LAC V058 Lean/flow accounting	0.08	0.32	0.44	0.34	0.45	0.12	0.49	0.33	0.25	0.00	1.00	0.50	0.40	0.35	0.23	0.29	0.07	0.37	0.18	0.38	0.26	0.40	0.33	0.23
MK V067 Mngmnt understood tools/ metho	0.19	0.42	0.64	0.42	0.52	0.36	0.36	0.41	0.45	0.15	0.49	0.84	0.46	0.56	0.43	0.29	0.23	0.38	0.20	0.54	0.42	0.38	0.39	0.46
MK V068 Mngmnt understood as a new cu	0.35	0.55	0.64	0.26	0.33	0.30	0.14	0.41	0.46	0.22	0.40	0.85	0.58	0.52	0.40	0.35	0.30	0.23	0.20	0.53	0.49	0.42	0.41	0.60
MK V105 Mngmnt contin. to learn and par	0.14	0.49	0.59	0.37	0.35	0.31	0.26	0.40	0.42	0.13	0.36	0.82	0.57	0.60	0.55	0.33	0.30	0.35	0.23	0.38	0.49	0.42	0.38	0.51
OC V016 Performance Enhanced	0.12	0.46	0.57	0.42	0.36	0.24	0.13	0.38	0.35	0.18	0.37	0.56	0.95	0.51	0.35	0.29	0.18	0.34	0.18	0.32	0.59	0.21	0.41	0.41
OC V040 Sustained Imp.	0.16	0.56	0.65	0.38	0.37	0.28	-0.04	0.44	0.42	0.07	0.35	0.60	0.88	0.56	0.30	0.16	0.32	0.42	0.10	0.35	0.56	0.29	0.41	0.40
OC V015 Competitive Advantage	0.00	0.42	0.56	0.39	0.37	0.25	0.19	0.42	0.39	0.05	0.38	0.57	0.89	0.53	0.48	0.36	0.24	0.33	0.23	0.36	0.49	0.17	0.39	0.42
PL V047 Mngmnt planned well	0.19	0.66	0.73	0.38	0.44	0.38	0.28	0.44	0.25	0.17	0.35	0.67	0.59	1.00	0.31	0.36	0.47	0.37	0.12	0.30	0.53	0.39	0.46	0.27
PR V092 Simple problem solving	0.34	0.21	0.46	0.21	0.33	0.34	0.16	0.49	0.50	0.23	0.23	0.54	0.41	0.31	1.00	0.33	0.22	0.23	0.27	0.40	0.38	0.46	0.40	0.61
PUL V094 Pull Systems	0.16	0.38	0.23	0.26	0.37	0.04	0.21	0.60	0.14	0.42	0.19	0.34	0.27	0.38	0.32	0.90	0.18	0.17	0.24	0.27	0.15	0.40	0.55	0.30
PUL V095 Kanban	0.29	0.28	0.23	0.35	0.45	0.07	0.26	0.61	0.13	0.25	0.32	0.36	0.28	0.28	0.28	0.93	0.16	0.21	0.45	0.23	0.27	0.42	0.54	0.45
REG V078 Program/Structure/Regularity	0.30	0.48	0.38	0.23	0.28	0.37	0.10	0.27	0.14	0.38	0.07	0.33	0.27	0.47	0.22	0.18	1.00	0.36	0.18	0.33	0.51	0.55	0.31	0.31
RES V062 Staff Capability	0.05	0.34	0.39	0.44	0.41	0.03	0.16	0.36	0.24	-0.07	0.35	0.37	0.40	0.33	0.22	0.06	0.26	0.81	0.05	0.32	0.34	0.22	0.14	0.26
RES V063 Technology Capability	0.08	0.27	0.31	0.54	0.52	0.17	0.28	0.53	0.31	-0.06	0.30	0.30	0.31	0.32	0.18	0.26	0.35	0.91	0.32	0.21	0.39	0.28	0.25	0.20
STA V096 Statistical Methods	0.30	0.12	0.09	0.24	0.32	0.32	0.34	0.36	0.14	0.16	0.18	0.25	0.19	0.12	0.27	0.39	0.18	0.24	1.00	0.18	0.21	0.31	0.33	0.26
STW V080 Standard work developed	0.34	0.28	0.48	0.21	0.27	0.34	0.22	0.38	0.36	0.29	0.38	0.58	0.38	0.30	0.40	0.27	0.33	0.29	0.18	1.00	0.33	0.50	0.30	0.57
SU V075 Growth mindset	0.21	0.58	0.66	0.40	0.40	0.28	0.20	0.39	0.26	0.26	0.30	0.59	0.50	0.42	0.27	0.14	0.37	0.38	0.14	0.31	0.86	0.28	0.46	0.41
SU V079 Individual support in adjusting	0.29	0.50	0.53	0.34	0.35	0.40	0.35	0.45	0.26	0.38	0.16	0.38	0.55	0.51	0.39	0.26	0.51	0.35	0.22	0.25	0.87	0.33	0.51	0.30
TPM V089 Total Productive Maintenance	0.49	0.38	0.38	0.24	0.36	0.31	0.26	0.39	0.27	0.42	0.40	0.48	0.25	0.39	0.46	0.45	0.55	0.30	0.31	0.50	0.35	1.00	0.43	0.55
V059 Flow focus	0.15	0.39	0.50	0.22	0.31	0.04	0.19	0.50	0.36	0.14	0.51	0.41	0.46	0.39	0.37	0.42	-0.01	0.22	0.06	0.17	0.41	0.17	0.61	0.32
V093 DefiningValue	0.00	0.43	0.31	0.24	0.18	0.23	0.10	0.45	0.20	0.50	0.09	0.29	0.38	0.31	0.28	0.43	0.29	0.16	0.20	0.28	0.40	0.28	0.78	0.17
V097 MappingValue Stream	0.38	0.47	0.35	0.29	0.37	0.30	0.27	0.41	0.15	0.38	0.18	0.36	0.17	0.33	0.25	0.48	0.36	0.15	0.46	0.21	0.43	0.48	0.80	0.37
VS V098 Visual Systems	0.52	0.23	0.47	0.21	0.40	0.21	0.01	0.38	0.47	0.24	0.23	0.62	0.46	0.27	0.61	0.42	0.31	0.26	0.26	0.57	0.41	0.55	0.38	1.00

Variables must load theirconsruct higher than any other construc Values > 0.6 highlighted

Figure 310 SEM K.4 indicator cross loadings

Negative relationships and p>0.01 highlighted	Original Sample (β)	Sample Mean	Standard Deviation	Standard Error	T Statistics	p -value (Significance)
5S->Visual Systems	0.37	0.38	0.07	0.07	5.13	0.00000
Communication->Employee Initiatives	0.35	0.35	0.08	0.08	4.20	0.00006
Communication->Guiding Coalition	-0.20	-0.20	0.09	0.09	2.29	0.02403
Communication->Kaizen Events	0.31	0.31	0.12	0.12	2.52	0.01348
Communication->Regularity	0.34	0.34	0.09	0.09	3.99	0.00013
Employee Initiatives->Guiding Coalition	0.65	0.65	0.11	0.11	6.00	0.00000
Employee Initiatives->Journey View	0.58	0.57	0.12	0.12	4.98	0.00000
Employee Initiatives->Support Employees	0.40	0.40	0.08	0.08	5.11	0.00000
Engage Customers->Outcomes	0.28	0.27	0.09	0.09	3.02	0.00324
Engage Suppliers->Engage Customers	0.62	0.62	0.08	0.08	7.79	0.00000
Engage Suppliers->Information Systems	0.41	0.41	0.09	0.09	4.63	0.00001
Engage Suppliers->Outcomes	-0.17	-0.17	0.09	0.09	1.98	0.05037
Guiding Coalition->5S	0.26	0.26	0.11	0.11	2.42	0.01723
Guiding Coalition->Kaizen Events	0.13	0.14	0.08	0.08	1.59	0.11540
Guiding Coalition->Problem Solving (Simple)	0.17	0.18	0.09	0.09	2.04	0.04435
Guiding Coalition->Regularity	0.18	0.18	0.09	0.09	1.89	0.06219
Guiding Coalition->Visual Systems	-0.19	-0.18	0.07	0.07	2.61	0.01063
Information Systems->Outcomes	-0.25	-0.26	0.09	0.09	2.92	0.00439
Information Systems->Satistical Methods	0.26	0.26	0.10	0.10	2.59	0.01111
Information Systems->Support Employees	0.14	0.14	0.06	0.06	2.21	0.02954
JIT->Engage Suppliers	0.49	0.48	0.08	0.08	5.89	0.00000
JIT->Pull/Kanban	0.78	0.78	0.07	0.07	10.85	0.00000
JIT->Resource	0.53	0.53	0.07	0.07	7.29	0.00000
JIT->Support Employees	0.20	0.20	0.09	0.09	2.16	0.03300
JIT->Value Flow	0.37	0.37	0.11	0.11	3.45	0.00083
Journey View->Problem Solving (Simple)	0.24	0.24	0.07	0.07	3.33	0.00124
Kaizen Events->5S	0.23	0.24	0.09	0.09	2.47	0.01528
Kaizen Events->TPM	0.35	0.35	0.10	0.10	3.60	0.00050
Lean/Flow Accounting->Kaizen Events	-0.17	-0.18	0.09	0.09	1.83	0.06970
Lean/Flow Accounting->Outcomes	0.32	0.33	0.08	0.08	4.10	0.00009
Lean/Flow Accounting->Regularity	-0.25	-0.24	0.09	0.09	2.79	0.00644
Lean/Flow Accounting->TPM	0.24	0.24	0.10	0.10	2.51	0.01388
Management Knowledge->Communication	0.26	0.26	0.11	0.11	2.25	0.02676
Management Knowledge->Employee Initiatives	0.55	0.54	0.08	0.08	7.04	0.00000
Management Knowledge->Engage Suppliers	0.25	0.25	0.08	0.08	3.07	0.00282
Management Knowledge->JIT	0.35	0.35	0.10	0.10	3.48	0.00076
Management Knowledge->Journey View	0.38	0.38	0.12	0.12	3.18	0.00199
Management Knowledge->Lean/Flow Accounting	0.50	0.50	0.07	0.07	7.45	0.00000
Management Knowledge->Planning	0.67	0.67	0.08	0.08	8.80	0.00000
Management Knowledge->Standard Work	0.44	0.43	0.10	0.10	4.30	0.00004
Management Knowledge->TPM	0.25	0.27	0.11	0.11	2.32	0.02236
Management Knowledge->Visual Systems	0.41	0.41	0.09	0.09	4.57	0.00001
Planning->Communication	0.48	0.48	0.11	0.11	4.22	0.00006
Planning->JIT	0.20	0.20	0.10	0.10	2.07	0.04140
Planning->Journey View	-0.43	-0.42	0.12	0.12	3.66	0.00041
Planning->Kaizen Events	-0.22	-0.22	0.11	0.11	1.95	0.05450
Planning->Outcomes	0.33	0.32	0.10	0.10	3.28	0.00148
Problem Solving (Simple)->Outcomes	0.12	0.13	0.08	0.08	1.64	0.10339
Pull/Kanban->Satistical Methods	0.32	0.32	0.09	0.09	3.37	0.00109
Pull/Kanban->Support Employees	-0.24	-0.24	0.09	0.09	2.70	0.00827
Pull/Kanban->Value Flow	0.35	0.36	0.10	0.10	3.49	0.00075
Pull/Kanban->Visual Systems	0.11	0.12	0.06	0.06	1.85	0.06708
Regularity->Support Employees	0.26	0.25	0.07	0.07	3.78	0.00027
Resource->Engage Customers	0.24	0.24	0.08	0.08	2.94	0.00411
Resource->Pull/Kanban	-0.21	-0.20	0.10	0.10	2.01	0.04775
Satistical Methods->TPM	0.15	0.15	0.09	0.09	1.67	0.09902
Standard Work->Visual Systems	0.24	0.23	0.10	0.10	2.38	0.01923
Support Employees->Outcomes	0.33	0.35	0.09	0.09	3.67	0.00041
TPM->5S	0.31	0.31	0.12	0.12	2.62	0.01022
TPM->Outcomes	-0.24	-0.24	0.10	0.10	2.49	0.01470
TPM->Regularity	0.47	0.46	0.10	0.10	4.72	0.00001
TPM->Standard Work	0.29	0.29	0.10	0.10	2.99	0.00352
Value Flow->Kaizen Events	0.42	0.42	0.11	0.11	3.89	0.00018
Value Flow->Support Employees	0.26	0.26	0.09	0.09	2.77	0.00681
Visual Systems->Outcomes	0.22	0.22	0.10	0.10	2.15	0.03436
Visual Systems->Problem Solving (Simple)	0.46	0.46	0.07	0.07	6.38	0.00000

Figure 311 SEM K.4 bootstrapped paths analysis (5000 times, individual sign changes allowed).

SEM K.5 Model Validation

	5S	Communication	Employee Initiatives (Enabled)	Engage Customers	Engage Suppliers	Guiding Coalition	JIT	Kaizen Events	Lean/Flow Accounting	Management Knowledge	Outcomes	Planning	Problem Solving (Simple)	Pull/Kanban	Regularity	Standard Work	Statistical Methods	Support Employee	TPM	Value Flow	Visual Systems
5S V086 5S System	1.00																				
COM V050 Mngmnt effective com. process		0.88																			
COM V051 Mngmnt vivid comm. strategy/vision		0.93																			
COM V052 Mngmnt comm. staff role		0.91																			
COM V053 Mngmnt vivid com. steps of change		0.88																			
EE V041 Worker Initiatives			0.88																		
EE V048 Easy for suggestion/improvements			0.86																		
ENC V101 Engaging customers				1.00																	
ENS V100 Engaging suppliers					1.00																
GC V077 Guiding coalition supporting						1.00															
JIT V087 Just In Time Manufacture							1.00														
KAI V090 Kaizen								1.00													
LAC V058 Lean/flow accounting									1.00												
MK V067 Mngmnt understood tools/ methods										0.84											
MK V068 Mngmnt understood as a new culture/ p										0.84											
MK V105 Mngmnt contin. to learn and participate										0.82											
OC V016 Performance Enhanced											0.85										
OC V040 Sustained Imp.											0.78										
OC V015 Competitive Advantage											0.86										
PL V047 Mngmnt planned well												1.00									
PR V091 5 Whys													0.89								
PR V092 Simple problem solving													0.94								
PUL V094 Pull Systems														0.93							
PUL V095 Kanban														0.90							
REG V072 Small wins prominent															0.82						
REG V078 Program/Structure/Regularity															0.87						
STA V096 Statistical Methods																	1.00				
STW V080 Standard work developed																1.00					
SU V075 Growth mindset																		0.85			
SU V079 Individual support in adjusting																		0.85			
TPM V089 Total Productive Maintenance																			1.00		
V093 DefiningValue																				0.87	
V097 MappingValue Stream																				0.88	
VS V098 Visual Systems																					1.00

Basic criterion for loading is >0.7. Lower loadings are accepted in exploratory work and removal of slightly lower loadings in PLS SEM is discouraged to support consistency at large.

Figure 312 SEM K.5 indicator loadings in outer model.

	5S	Communication	Employee Initiatives (Enabled)	Engage Customers	Engage Suppliers	Guiding Coalition	JIT	Kaizen Events	Lean/Flow Accounting	Management Knowledge	Outcomes	Planning	Problem Solving (Simple)	Pull/Kanban	Regularity	Standard Work	Statistical Methods	Support Employees	TPM	Value Flow	Visual Systems
5S V086 5S System	1.00	0.33	0.42	0.11	0.30	0.35	0.40	0.44	0.09	0.36	0.27	0.17	0.57	0.42	0.47	0.35	0.23	0.38	0.45	0.41	0.58
COM V050 Mngmnt effective com. process	0.23	0.88	0.65	0.50	0.63	0.30	0.46	0.30	0.45	0.47	0.66	0.60	0.35	0.40	0.52	0.46	0.25	0.60	0.32	0.47	0.51
COM V051 Mngmnt vivid comm. strategy/vision	0.29	0.93	0.57	0.43	0.51	0.26	0.39	0.31	0.43	0.51	0.54	0.54	0.31	0.33	0.43	0.41	0.22	0.52	0.41	0.49	0.49
COM V052 Mngmnt comm. staff role	0.31	0.91	0.61	0.46	0.60	0.36	0.46	0.31	0.58	0.48	0.59	0.63	0.39	0.43	0.48	0.39	0.43	0.56	0.44	0.54	0.43
COM V053 Mngmnt vivid com. steps of change	0.36	0.88	0.56	0.30	0.49	0.39	0.51	0.38	0.48	0.57	0.53	0.62	0.32	0.43	0.51	0.43	0.25	0.51	0.43	0.54	0.48
EE V041 Worker Initiatives	0.37	0.54	0.88	0.33	0.43	0.31	0.50	0.58	0.35	0.62	0.65	0.47	0.64	0.53	0.61	0.51	0.20	0.73	0.37	0.61	0.65
EE V048 Easy for suggestion/improvements	0.35	0.61	0.86	0.15	0.37	0.33	0.39	0.27	0.30	0.52	0.66	0.54	0.36	0.55	0.46	0.45	0.29	0.60	0.30	0.27	0.39
ENC V101 Engaging customers	0.11	0.47	0.28	1.00	0.59	0.13	0.22	0.16	0.24	0.30	0.40	0.32	0.41	0.08	0.28	0.36	0.23	0.38	0.28	0.45	0.31
ENS V100 Engaging suppliers	0.30	0.62	0.47	0.59	1.00	0.30	0.56	0.22	0.45	0.46	0.54	0.52	0.37	0.42	0.29	0.52	0.33	0.45	0.27	0.56	0.40
GC V077 Guiding coalition supporting	0.35	0.37	0.37	0.13	0.30	1.00	0.42	0.31	0.06	0.28	0.39	0.32	0.32	0.42	0.62	0.48	0.30	0.52	0.30	0.28	0.31
JIT V087 Just In Time Manufacture	0.40	0.51	0.51	0.22	0.56	0.42	1.00	0.47	0.37	0.52	0.45	0.49	0.47	0.57	0.54	0.50	0.24	0.45	0.28	0.47	0.45
KAI V090 Kaizen	0.44	0.36	0.50	0.16	0.22	0.31	0.47	1.00	0.33	0.43	0.39	0.29	0.68	0.61	0.56	0.37	0.34	0.56	0.56	0.49	0.48
LAC V058 Lean/flow accounting	0.09	0.54	0.37	0.24	0.45	0.06	0.37	0.33	1.00	0.45	0.47	0.49	0.28	0.46	0.27	0.13	0.41	0.36	0.38	0.46	0.27
MK V067 Mngmnt understood tools/ methods	0.28	0.36	0.53	0.14	0.24	0.13	0.29	0.36	0.38	0.84	0.43	0.46	0.36	0.40	0.42	0.24	0.23	0.41	0.26	0.38	0.41
MK V068 Mngmnt understood as a new culture/ p	0.24	0.45	0.53	0.23	0.44	0.09	0.45	0.26	0.42	0.84	0.41	0.50	0.32	0.34	0.32	0.25	0.18	0.42	0.26	0.43	0.40
MK V105 Mngmnt contin. to learn and participate	0.36	0.57	0.59	0.34	0.45	0.43	0.53	0.43	0.33	0.82	0.52	0.41	0.46	0.49	0.55	0.48	0.36	0.61	0.34	0.55	0.54
OC V016 Performance Enhanced	0.25	0.50	0.65	0.33	0.47	0.36	0.38	0.32	0.41	0.41	0.85	0.37	0.30	0.48	0.43	0.43	0.25	0.62	0.28	0.38	0.42
OC V040 Sustained Imp.	0.27	0.64	0.69	0.39	0.48	0.33	0.38	0.31	0.34	0.57	0.78	0.48	0.36	0.47	0.48	0.56	0.19	0.58	0.24	0.41	0.45
OC V015 Competitive Advantage	0.12	0.45	0.52	0.26	0.37	0.27	0.37	0.34	0.43	0.36	0.86	0.31	0.30	0.41	0.37	0.30	0.13	0.49	0.34	0.22	0.28
PL V047 Mngmnt planned well	0.17	0.67	0.58	0.32	0.52	0.32	0.49	0.29	0.49	0.54	0.47	1.00	0.35	0.46	0.51	0.47	0.50	0.46	0.26	0.55	0.39
PR V091 5 Whys	0.48	0.32	0.40	0.30	0.32	0.23	0.47	0.62	0.27	0.37	0.26	0.28	0.89	0.49	0.43	0.30	0.35	0.42	0.48	0.57	0.49
PR V092 Simple problem solving	0.55	0.37	0.64	0.43	0.36	0.34	0.39	0.63	0.25	0.47	0.43	0.36	0.94	0.51	0.58	0.39	0.33	0.58	0.54	0.62	0.58
PUL V094 Pull Systems	0.39	0.47	0.59	0.12	0.46	0.45	0.59	0.55	0.37	0.49	0.54	0.43	0.51	0.93	0.45	0.49	0.40	0.57	0.45	0.55	0.48
PUL V095 Kanban	0.39	0.33	0.55	0.02	0.31	0.31	0.44	0.56	0.47	0.42	0.45	0.41	0.49	0.90	0.42	0.36	0.43	0.45	0.42	0.41	0.36
REG V072 Small wins prominent	0.28	0.39	0.60	0.18	0.10	0.42	0.38	0.46	0.08	0.35	0.39	0.34	0.47	0.34	0.82	0.39	0.19	0.60	0.20	0.28	0.37
REG V078 Program/Structure/Regularity	0.50	0.52	0.46	0.28	0.38	0.62	0.53	0.49	0.36	0.53	0.48	0.52	0.47	0.46	0.87	0.46	0.48	0.59	0.32	0.54	0.41
STA V096 Statistical Methods	0.23	0.32	0.28	0.23	0.33	0.30	0.24	0.34	0.41	0.32	0.24	0.50	0.36	0.45	0.41	0.36	1.00	0.39	0.35	0.38	0.15
STW V080 Standard work developed	0.35	0.47	0.55	0.36	0.52	0.48	0.50	0.37	0.13	0.41	0.53	0.47	0.39	0.47	0.51	1.00	0.36	0.55	0.20	0.39	0.41
SU V075 Growth mindset	0.36	0.55	0.69	0.25	0.36	0.37	0.40	0.43	0.29	0.61	0.55	0.38	0.43	0.50	0.52	0.44	0.30	0.85	0.49	0.49	0.44
SU V079 Individual support in adjusting	0.29	0.48	0.61	0.40	0.41	0.51	0.37	0.52	0.33	0.39	0.61	0.40	0.52	0.45	0.67	0.49	0.37	0.85	0.38	0.42	0.47
TPM V089 Total Productive Maintenance	0.45	0.44	0.39	0.28	0.27	0.30	0.28	0.56	0.38	0.35	0.34	0.26	0.56	0.47	0.31	0.20	0.35	0.51	1.00	0.39	0.46
V093 DefiningValue	0.32	0.54	0.41	0.42	0.53	0.28	0.47	0.44	0.38	0.53	0.37	0.52	0.52	0.51	0.44	0.38	0.37	0.53	0.43	0.87	0.42
V097 MappingValue Stream	0.39	0.45	0.50	0.37	0.44	0.21	0.36	0.41	0.43	0.44	0.35	0.43	0.61	0.41	0.43	0.30	0.30	0.41	0.25	0.88	0.54
VS V098 Visual Systems	0.58	0.53	0.61	0.31	0.40	0.31	0.45	0.48	0.27	0.55	0.47	0.39	0.59	0.46	0.46	0.41	0.15	0.54	0.46	0.55	1.00

Variables must load theirconsruct higher than any other construct. Values > 0.6 highlighted

Figure 313 SEM K.5 indicator cross loadings

Negative relationships and p>0.01 highlighted	Original Sample (β)	Sample Mean	Standard Deviation	Standard Error	T Statistics	p -value (Significance)
5S->Problem Solving (Simple)	0.25	0.25	0.09	0.09	2.83	0.00581
Communication->Employee Initiatives (Enabled)	0.30	0.30	0.08	0.08	3.66	0.00044
Communication->Engage Suppliers	0.62	0.62	0.07	0.07	9.02	0.00000
Communication->Guiding Coalition	0.36	0.36	0.11	0.11	3.26	0.00162
Communication->Lean/Flow Accounting	0.42	0.42	0.10	0.10	4.39	0.00003
Communication->Support Employees	0.26	0.26	0.10	0.10	2.69	0.00856
Employee Initiatives (Enabled)->Outcomes	0.72	0.73	0.08	0.08	9.53	0.00000
Engage Customers->Outcomes	0.22	0.22	0.07	0.07	2.93	0.00441
Engage Customers->Value Flow	0.34	0.34	0.07	0.07	4.61	0.00001
Engage Suppliers->Engage Customers	0.59	0.59	0.09	0.09	6.79	0.00000
Guiding Coalition->Regularity	0.50	0.50	0.08	0.08	6.39	0.00000
JIT->5S	0.21	0.22	0.09	0.09	2.45	0.01622
JIT->Pull/Kanban	0.42	0.42	0.10	0.10	4.03	0.00012
JIT->Standard Work	0.44	0.44	0.09	0.09	4.98	0.00000
Kaizen Events->Problem Solving (Simple)	0.40	0.40	0.09	0.09	4.42	0.00003
Kaizen Events->Regularity	0.41	0.41	0.08	0.08	4.95	0.00000
Kaizen Events->TPM	0.56	0.56	0.07	0.07	7.75	0.00000
Lean/Flow Accounting->5S	-0.21	-0.21	0.09	0.09	2.35	0.02093
Lean/Flow Accounting->Guiding Coalition	-0.33	-0.33	0.10	0.10	3.39	0.00107
Lean/Flow Accounting->Outcomes	0.20	0.20	0.07	0.07	2.77	0.00697
Lean/Flow Accounting->Statistical Methods	0.25	0.26	0.11	0.11	2.41	0.01815
Management Knowledge->Communication	0.29	0.29	0.10	0.10	2.78	0.00670
Management Knowledge->JIT	0.36	0.36	0.11	0.11	3.23	0.00175
Management Knowledge->Planning	0.54	0.54	0.09	0.09	6.14	0.00000
Management Knowledge->Pull/Kanban	0.28	0.29	0.11	0.11	2.51	0.01393
Management Knowledge->Value Flow	0.27	0.26	0.10	0.10	2.76	0.00717
Management Knowledge->Visual Systems	0.28	0.28	0.10	0.10	2.67	0.00910
Planning->Communication	0.51	0.51	0.08	0.08	6.01	0.00000
Planning->JIT	0.29	0.30	0.10	0.10	3.00	0.00359
Problem Solving (Simple)->Employee Initiatives (Enabled)	0.20	0.20	0.08	0.08	2.48	0.01513
Problem Solving (Simple)->Outcomes	-0.18	-0.18	0.08	0.08	2.31	0.02316
Pull/Kanban->Guiding Coalition	0.41	0.41	0.10	0.10	4.15	0.00008
Pull/Kanban->Kaizen Events	0.49	0.49	0.10	0.10	5.04	0.00000
Pull/Kanban->Lean/Flow Accounting	0.27	0.27	0.08	0.08	3.30	0.00140
Pull/Kanban->Statistical Methods	0.34	0.33	0.10	0.10	3.24	0.00169
Pull/Kanban->Support Employees	0.23	0.23	0.09	0.09	2.41	0.01808
Pull/Kanban->Value Flow	0.37	0.37	0.08	0.08	4.74	0.00001
Regularity->Support Employees	0.45	0.46	0.08	0.08	5.35	0.00000
Standard Work->Visual Systems	0.21	0.21	0.08	0.08	2.62	0.01042
Statistical Methods->Standard Work	0.26	0.26	0.10	0.10	2.60	0.01102
Statistical Methods->Visual Systems	-0.23	-0.23	0.07	0.07	3.03	0.00327
Support Employees->Employee Initiatives (Enabled)	0.47	0.48	0.07	0.07	6.57	0.00000
TPM->5S	0.28	0.28	0.10	0.10	2.85	0.00552
TPM->Visual Systems	0.28	0.29	0.08	0.08	3.50	0.00074
Value Flow->Kaizen Events	0.23	0.24	0.10	0.10	2.34	0.02176
Value Flow->Problem Solving (Simple)	0.35	0.36	0.09	0.09	4.12	0.00009
Value Flow->Visual Systems	0.29	0.30	0.10	0.10	2.84	0.00563
Visual Systems->5S	0.42	0.42	0.09	0.09	4.77	0.00001

Figure 314 SEM K.5 bootstrapped paths analysis (5000 times, individual sign changes allowed)

13.2.4 SEM Exploration of the Lean Knowledge-Based View

Below are SEM models as examples of exploration. These models passed quality criteria but exhibited skew due to the way scales were formed.

- This exploration was informative but **the models themselves are not representations of causality** for lean success; they are explorative but faulty and needed adjustment.
- See discussion under SEM B Intermediate Exploration (Constructs and Model), p. 244.

SEM B.2 – B.4: Categorical Exploration by Situational Variables

SEM B.2 through B.4 were aimed at addressing Hypothesis 3: The key success factors for lean do not differ due to business size, and product mix. This analysis showed weakness of constructs. Constructs needed higher indicator weightings for reliability. Specific relationships expected were not observed (e.g. importance of JIT in high volume manufacture).

SEM B.2 Business Size Small, 11 -100 Employees

Lean Knowledge-Based View for small businesses of 11 -100 Employees is explored as SEM B.2. There were 80 cases 90%+ complete in this small business category.

Indicator Loadings

	Advanced Methods	Enabl Employees	Extended VS	Mngmnt Knowledge	Momentum/ Regularity	Outcomes	Resources	Simple Methods
AM_V087_Just_In_Time_Manufacture	0.64							
AM_V089_Total_Productive_Maintenance	0.58							
AM_V094_Pull_Systems	0.81							
AM_V095_Kanban	0.72							
EE_V039_Staff_in_planning.		0.55						
EE_V041_Worker__Initiatives		0.86						
EE_V048_Easy_for_suggestion/improvement		0.84						
EE_V057_Involved_all_Staff		0.87						
EVS_V100_Engaging_suppliers			0.87					
EVS_V101_Engaging_customers			0.92					
MK_V055_Mngmnt_had_exclnt_lean_knwld				0.71				
MK_V067_Mgmt_understood_tools/_method				0.85				
MK_V068_Mgmt_understood_as_a_new_cu				0.78				
MK_V105_Mngmnt_contin._to_learn_and_p				0.77				
MK_V106_Mgmt_established_lean_knowled				0.73				
MR_V032_Momentum_Constant					0.73			
MR_V049_Culture_initial_priority					0.75			
MR_V072_Small_wins_prominent					0.66			
MR_V078_Program/Structure/Regularity					0.66			
OC_V016_Performance_Enhanced						0.89		
OC_V017_Staff_Morale_Incr.						0.74		
OC_V038_New_Cult_Developed						0.88		
OC_V040_Sustained_Imp.						0.81		
OC_V044_Developed_a_self-improving_org.						0.81		
OC__V015_Competitive_Advantage						0.79		
RC_V062_Staff_Capability							0.77	
RC_V063_Technology_Capability							0.52	
RC_V064_Management_Capability							0.87	
RC_V066_Impl._Leader_Capability							0.72	
SM_V080_Standard_work_developed								0.77
SM_V091_5_Whys								0.74
SM_V092_Simple_problem_solving								0.77
SM_V098_Visual_Systems								0.88
SM_V099_Root_Cause_Analysis								0.79

Basic criterion for loading is >0.7. Lower loadings are accepted in exploratory work and removal of slightly lower loadings in PLS SEM is discouraged to support consistency at large.

Figure 315 SEM B. 2 Indicator loadings in outer model.

A low indicator loading of 0.55 was observed for V039 involvement and communication with staff in planning. Indications are this construct is more related to communication than involvement of staff i.e. the Enabling Employee Initiatives construct it was loading. Communication may be more natural and less of an effort in smaller businesses, (Figure 315).

AM V089 Total Productive Maintenance loaded low i.e. lower than in the generic case (0.58 cf. 0.77). Typically, manufacturing volumes were lower and product mix was higher in the small manufacturing businesses surveyed. Total Productive Maintenance is more suited and easier to apply in low-volume high-variety than the advanced process techniques such as JIT with pull systems. It is logical that Total Productive Maintenance loading decreased.

Both constructs were retained initially as recommended for maintaining consistency at large.

Quality Overview

	AVE	Composite Reliability	Cronbachs Alpha	Redund-ancy	R Square	Communality
Significance criteria	*>0.5*	*>0.6**	*>0.7***		*>0.1*	
Minimum Observed	0.48	0.79	0.66		0.13	0.48
Advanced Methods	0.48	0.79	0.66	0.09	0.20	0.48
Enabl Employees	0.63	0.87	0.80	0.32	0.53	0.63
ExtendedVS	0.80	0.89	0.76	0.16	0.19	0.80
Management knowledge	0.59	0.88	0.83	N/A	N/A	0.59
Momentum/Regularity	0.49	0.80	0.66	0.22	0.47	0.49
Outcomes	0.67	0.92	0.90	-0.01	0.73	0.67
Resources	0.54	0.82	0.72	0.07	0.13	0.54
Simple Methods	0.63	0.89	0.85	0.18	0.31	0.63

**Composite Reliability >0.6 for exploratory research or >0.7 for developed research.*
***Cronbachs Alpha is included for reference. Composite reliability is prefered over Conbach's Alpha for PLS-SEM. Refer: Hair J. F. 2011, PLS-SEM: Indeed a Silver Bullet*

Goodness of fit Calculation

Avg R^2	***Avg Com.***
0.37	*0.60*
Gof =	*0.47*

Gof = SQRT((Avg R^2)(Avg Com.))*
Gof > 0.31 recommended

Fornell - Larcker Criterion (Fornell & Larcker, 1981)

	Advanced Methods	Enabl Employees	Extended VS	Mngmnt Knowledge	Momentum/ Regularity	Outcomes	Resources	Simple Methods
Advanced Methods	**0.70**	####						
Enabl Employees	0.42	**0.79**						
ExtendedVS	0.33	0.51	**0.90**					
Management knowledge	0.45	0.73	0.44	**0.77**	####			
Momentum/Regularity	0.31	0.77	0.44	0.69	**0.70**	####		
Outcomes	0.33	0.81	0.52	0.66	0.78	**0.82**		
Resources	0.03	0.38	0.27	0.36	0.43	0.41	**0.73**	
Simple Methods	0.34	0.60	0.40	0.56	0.45	0.51	0.32	**0.79**

Latent Variable Correlations compared with √(AVE), i.e. check √(AVE) >factor loading, Bold = √(AVE)

Figure 316 SEM B.2 quality Analysis Tables

Further quality analysis (Figure 316) showed sufficient reliability and goodness of fit. The small business case showed poorer AVE and the Fornell - Larcker criterion for discriminant validity was not met. Fornell - Larcker was not met for Enabling Employee Initiatives or Momentum/Regularity and was border-line for Outcomes. Cross loadings matrix, Figure 54 showed significant cross loadings in each of these constructs. The discriminant validity issues were intensified in the small business case.

> This demonstrates especially strong relationships between enabling employee initiatives and building the culture and momentum for lean success in small businesses.

Cross loadings

	Advanced Methods	Enabl Employees	Extended VS	Mngmnt Knowledge	Momentum/ Regularity	Outcomes	Resources	Simple Methods
AM_V087_Just_In_Time_Manufacture	0.64	0.26	0.34	0.26	0.25	0.25	0.04	0.15
AM_V089_Total_Productive_Maintenance	0.58	0.23	0.15	0.24	0.19	0.06	0.12	0.43
AM_V094_Pull_Systems	0.81	0.40	0.29	0.41	0.32	0.37	0.02	0.22
AM_V095_Kanban	0.72	0.23	0.08	0.28	0.04	0.11	-0.10	0.25
EE_V039_Staff_in_planning.	0.34	0.55	0.44	0.24	0.38	0.28	0.33	0.26
EE_V041_Worker__Initiatives	0.33	0.86	0.45	0.64	0.68	0.74	0.37	0.63
EE_V048_Easy_for_suggestion/improvement	0.35	0.84	0.35	0.66	0.67	0.72	0.35	0.35
EE_V057_Involved_all_Staff	0.37	0.87	0.47	0.64	0.65	0.69	0.20	0.59
EVS_V100_Engaging_suppliers	0.39	0.43	0.87	0.37	0.30	0.39	0.12	0.28
EVS_V101_Engaging_customers	0.23	0.49	0.92	0.42	0.47	0.53	0.34	0.43
MK_V055_Mngmnt_had_exclnt_lean_knwld	0.47	0.54	0.33	0.71	0.34	0.41	0.25	0.42
MK_V067_Mgmt_understood_tools/_method	0.32	0.51	0.27	0.85	0.49	0.51	0.26	0.43
MK_V068_Mgmt_understood_as_a_new_cu	0.24	0.55	0.32	0.78	0.63	0.49	0.20	0.48
MK_V105_Mngmnt_contin._to_learn_and_p	0.42	0.73	0.39	0.77	0.65	0.66	0.34	0.44
MK_V106_Mgmt_established_lean_knowled	0.23	0.39	0.37	0.73	0.45	0.36	0.33	0.35
MR_V032_Momentum_Constant	0.21	0.45	0.22	0.43	0.73	0.54	0.19	0.13
MR_V049_Culture_initial_priority	0.28	0.71	0.42	0.71	0.75	0.60	0.46	0.48
MR_V072_Small_wins_prominent	0.11	0.47	0.28	0.33	0.66	0.56	0.23	0.21
MR_V078_Program/Structure/Regularity	0.28	0.49	0.28	0.37	0.66	0.50	0.29	0.40
OC_V016_Performance_Enhanced	0.33	0.70	0.46	0.51	0.67	0.89	0.25	0.36
OC_V017_Staff_Morale_Incr.	0.19	0.57	0.36	0.38	0.51	0.74	0.22	0.33
OC_V038_New_Cult_Developed	0.28	0.70	0.45	0.62	0.73	0.88	0.33	0.47
OC_V040_Sustained_Imp.	0.33	0.75	0.51	0.61	0.71	0.81	0.47	0.46
OC_V044_Developed_a_self-improving_org.	0.22	0.67	0.47	0.62	0.66	0.81	0.42	0.49
OC__V015_Competitive_Advantage	0.25	0.56	0.29	0.43	0.51	0.79	0.31	0.37
RC_V062_Staff_Capability	0.07	0.36	0.29	0.24	0.35	0.38	0.77	0.28
RC_V063_Technology_Capability	0.02	0.01	0.04	0.20	-0.02	0.05	0.52	0.04
RC_V064_Management_Capability	0.03	0.39	0.22	0.39	0.46	0.38	0.87	0.28
RC_V066_Impl._Leader_Capability	-0.07	0.18	0.16	0.18	0.28	0.26	0.72	0.27
SM_V080_Standard_work_developed	0.28	0.53	0.42	0.45	0.39	0.50	0.24	0.77
SM_V091_5_Whys	0.30	0.41	0.10	0.31	0.21	0.25	0.10	0.74
SM_V092_Simple_problem_solving	0.13	0.40	0.26	0.45	0.31	0.32	0.33	0.77
SM_V098_Visual_Systems	0.40	0.60	0.43	0.58	0.51	0.52	0.29	0.88
SM_V099_Root_Cause_Analysis	0.19	0.35	0.26	0.31	0.27	0.29	0.28	0.79

Variables must load their consruct higher than any other construct. Values > 0.6 highlighted

Figure 317 Sem B.2 Indicator Cross loadings

Outer measurement model needed modification for discriminant validity. Variables of immediate interest were:

V039 Staff in Planning, for its low indicator loading in this case.

V049 Culture Initial Priority and V040 Sustained Implementation due to high cross loadings and presence in the relevant constructs

V105 Management continued to learn and participate due to its high cross loadings.

Removing V049 Culture Initial Priority produced the most discriminant solution (Figure 318). This reduced the Momentum/Regularity construct to 3 indicators. From 11 explorative iterations, this was the most satisfactory outcome. Reducing the indicator number to 3 is not preferred but acceptable.

This high cross loading indicates the extreme importance of building culture as a priority to the outcomes of lean in small businesses.

Staff in Planning (V039) appeared specific to the small business case, eliminating it did not sufficiently affect the cross loadings but did increase AVE for Enabling Employees from 0.63 to 0.75

V049 Culture Initial Priority was removed from Momentum/Regularity. It was trailed as a single indicator latent construct but in this form did not show significant path to outcomes (β_{abs}=0.02, t-statistic=0.29) and was removed. Staff in Planning (V039) was removed Enabling Employees. This formed the modified SEM B.2.1

Quality validation with the modified construct still showed minor issues; see Figure 318 and Figure 319. AVE was borderline/low, 0.48 for Advanced Methods and Fornell – Larcker was also borderline/low (Figure 318). Fornell – Larcker showed Outcomes √(AVE) of 0.81, slightly lower than correlation of 0.83 with Enabling Employees. Cross loadings (Figure 319) were investigated for target indicator removal. This was trivial difference but additional steps were taken to ensure Fornell – Larcker criterion was met.

Quality Overview

	AVE	Composite Reliability	Cronbachs Alpha	Redund-ancy	R Square	Communality
Significance criteria	*>0.5*	*>0.6**	*>0.7***		*>0.1*	
Minimum Observed	0.48	0.78	0.60		0.13	0.48
Advanced Methods	0.48	0.78	0.66	0.09	0.20	0.48
Enabl Employees	0.74	0.89	0.82	0.42	0.56	0.74
ExtendedVS	0.78	0.88	0.73	0.15	0.20	0.78
Management knowledge	0.58	0.87	0.82	N/A	N/A	0.58
Momentum/Regularity	0.56	0.79	0.60	0.14	0.26	0.56
Outcomes	0.66	0.92	0.90	-0.01	0.77	0.66
Resources	0.54	0.82	0.72	0.07	0.13	0.54
Simple Methods	0.62	0.89	0.85	0.18	0.31	0.62

**Composite Reliability >0.6 for exploratory research or >0.7 for developed research.*
***Cronbachs Alpha is included for reference Composite reliability is prefered over Conbach's Alpha for PLS-SEM. Refer: Hair J. F. 2011, PLS-SEM: Indeed a Silver*

Goodness of fit Calculation

Avg R^2	*Avg Com.*
0.35	*0.62*
Gof =	*0.46*

Gof = SQRT((Avg R^2)(Avg Com.))*
Gof > 0.31 recommended

Fornell - Larcker Criterion (Fornell & Larcker, 1981)

	Advanced Methods	Enabl Employees	Extended VS	Mngmnt Knowledge	Momentum/ Regularity	Outcomes	Resources	Simple Methods
Advanced Methods	**0.69**							
Enabl Employees	0.40	**0.86**						
ExtendedVS	0.33	0.49	**0.89**					
Management knowledge	0.44	0.75	0.44	**0.76**				
Momentum/Regularity	0.26	0.64	0.34	0.51	**0.75**			
Outcomes	0.33	0.83	0.53	0.66	0.71	**0.81**	<--Border line	
Resources	0.02	0.36	0.27	0.37	0.32	0.42	**0.73**	
Simple Methods	0.33	0.60	0.41	0.56	0.32	0.51	0.32	**0.79**

Latent Variable Correlations compared with √(AVE), i.e. check √(AVE) >factor loading, Bold = √(AVE)

Figure 318 SEM B.2.1, Indicators V039 and V049 removed - Quality Analysis Tables

Cross loadings

	Advanced Methods	Enabl Employees	Extended VS	Mngmnt Knowledge	Momentum/ Regularity	Outcomes	Resources	Simple Methods
AM_V087_Just_In_Time_Manufacture	0.63	0.23	0.33	0.25	0.17	0.23	0.03	0.14
AM_V089_Total_Productive_Maintenance	0.57	0.22	0.15	0.23	0.15	0.05	0.11	0.42
AM_V094_Pull_Systems	0.82	0.38	0.29	0.41	0.30	0.37	0.03	0.22
AM_V095_Kanban	0.72	0.23	0.08	0.28	0.01	0.10	-0.11	0.25
EE_V041_Worker__Initiatives	0.33	0.87	0.45	0.64	0.57	0.74	0.37	0.62
EE_V048_Easy_for_suggestion/improvement	0.36	0.84	0.35	0.65	0.53	0.71	0.34	0.35
EE_V057_Involved_all_Staff	0.35	0.87	0.46	0.65	0.54	0.69	0.21	0.59
EVS_V100_Engaging_suppliers	0.39	0.39	0.85	0.35	0.22	0.38	0.11	0.27
EVS_V101_Engaging_customers	0.22	0.47	0.92	0.42	0.37	0.54	0.34	0.43
MK_V055_Mngmnt_had_exclnt_lean_knwld	0.48	0.54	0.33	0.69	0.21	0.40	0.24	0.41
MK_V067_Mgmt_understood_tools/_method	0.33	0.54	0.27	0.84	0.30	0.51	0.26	0.43
MK_V068_Mgmt_understood_as_a_new_cu	0.22	0.55	0.32	0.77	0.45	0.50	0.21	0.47
MK_V105_Mngmnt_contin._to_learn_and_p	0.40	0.75	0.39	0.77	0.57	0.67	0.35	0.44
MK_V106_Mgmt_established_lean_knowled	0.23	0.40	0.37	0.73	0.34	0.36	0.33	0.35
MR_V032_Momentum_Constant	0.22	0.45	0.22	0.43	0.78	0.53	0.18	0.13
MR_V072_Small_wins_prominent	0.09	0.50	0.28	0.34	0.74	0.56	0.23	0.21
MR_V078_Program/Structure/Regularity	0.27	0.48	0.28	0.37	0.72	0.50	0.29	0.40
OC_V016_Performance_Enhanced	0.33	0.70	0.46	0.51	0.63	0.89	0.25	0.36
OC_V017_Staff_Morale_Incr.	0.21	0.58	0.35	0.36	0.43	0.71	0.21	0.32
OC_V038_New_Cult_Developed	0.26	0.72	0.44	0.63	0.66	0.87	0.33	0.47
OC_V040_Sustained_Imp.	0.33	0.75	0.51	0.61	0.64	0.81	0.48	0.45
OC_V044_Developed_a_self-improving_org.	0.19	0.69	0.46	0.63	0.61	0.81	0.42	0.48
OC__V015_Competitive_Advantage	0.26	0.56	0.29	0.42	0.43	0.78	0.30	0.36
RC_V062_Staff_Capability	0.06	0.34	0.29	0.24	0.25	0.38	0.77	0.28
RC_V063_Technology_Capability	0.01	0.01	0.04	0.20	-0.05	0.06	0.52	0.04
RC_V064_Management_Capability	0.03	0.36	0.22	0.40	0.33	0.39	0.87	0.28
RC_V066_Impl._Leader_Capability	-0.07	0.18	0.16	0.18	0.25	0.26	0.71	0.27
SM_V080_Standard_work_developed	0.28	0.54	0.42	0.45	0.32	0.50	0.24	0.77
SM_V091_5_Whys	0.29	0.42	0.10	0.31	0.16	0.26	0.11	0.74
SM_V092_Simple_problem_solving	0.12	0.40	0.25	0.46	0.13	0.33	0.33	0.77
SM_V098_Visual_Systems	0.40	0.59	0.43	0.57	0.39	0.51	0.28	0.87
SM_V099_Root_Cause_Analysis	0.18	0.34	0.27	0.31	0.17	0.29	0.28	0.79

Variables must load their consruct higher than any other construct. Values > 0.6 highlighted

Figure 319 Cross loadings, SEM B.2.1, Indicators V039 and V049 removed - Quality Analysis Tables

Cross loadings, Figure 319, showed V040 Sustained Implementation with highest cross loadings. Removing this shifted correlation of Enabling Employees with Outcomes to 0.80[205], satisfying Fornell – Larcker. Resultant quality tables are Figure 320 and Figure 321, show all quality criterion are met except AVE>0.5.

AVE greater than 0.5 is recommended (Fornell & Larcker, 1981; Henseler et al., 2009). Testing by four different data selections (generic case; low-mix high-volume; high mix low-volume; and 101-500 employee data sets) showed AVE>0.5 was achieved for these. Although higher AVE was desirable in the small business (10-100 employees) analysis, 0.49 was sufficient considering (a) the exploratory purposes of this analysis, (b) the value (0.49) was border-line to acceptable, (c) model was acceptable in all other quality criterion and (d) the general weakness of this construct is expected in smaller business case. AVE was expected to rise with eliminated paths also.

[205] Iterations showed equivalent model quality was obtained independent of which of the following indicators were removed: V038 New culture developed, V040 Sustained implementation, and V044 Developed a self-improving organisation.

Quality Overview

	AVE	Composite Reliability	Cronbachs Alpha	Redund-ancy	R Square	Communality
Significance criteria	*>0.5*	*>0.6**	*>0.7***		*>0.1*	
Minimum Observed	0.49	0.79	0.62		0.14	0.49
Advanced Methods	0.49	0.79	0.67	0.10	0.20	0.49
Enabl Employees	0.74	0.89	0.82	0.42	0.57	0.74
ExtendedVS	0.80	0.89	0.75	0.15	0.19	0.80
Management knowledge	0.59	0.88	0.82	N/A	N/A	0.59
Momentum/Regularity	0.57	0.80	0.62	0.16	0.27	0.57
Outcomes	0.69	0.92	0.89	-0.02	0.71	0.69
Resources	0.52	0.81	0.70	0.07	0.14	0.52
Simple Methods	0.61	0.89	0.84	0.17	0.31	0.61

**Composite Reliability >0.6 for exploratory research or >0.7 for developed research.*
***Cronbachs Alpha is included for reference Composite reliability is prefered over Conbach's Alpha for PLS-SEM. Refer: Hair J. F. 2011, PLS-SEM: Indeed a Silver*

Goodness of fit Calculation

Avg R^2	*Avg Com.*
0.34	*0.63*
Gof =	*0.46*

Gof = SQRT((Avg R^2)(Avg Com.))*
Gof > 0.31 recommended

Fornell - Larcker Criterion (Fornell & Larcker, 1981)

	Advanced Methods	Enabl Employees	Extended VS	Mngmnt Knowledge	Momentum/ Regularity	Outcomes	Resources	Simple Methods
Advanced Methods	**0.70**							
Enabl Employees	0.39	**0.86**						
ExtendedVS	0.29	0.50	**0.89**					
Management knowledge	0.45	0.75	0.44	**0.77**				
Momentum/Regularity	0.27	0.65	0.36	0.52	**0.75**			
Outcomes	0.29	0.80	0.52	0.63	0.70	**0.83**	<--Border line	
Resources	0.04	0.35	0.26	0.37	0.31	0.36	**0.72**	
Simple Methods	0.35	0.58	0.36	0.55	0.31	0.45	0.32	**0.78**

Latent Variable Correlations compared with √(AVE), i.e. check √(AVE) >factor loading, Bold = √(AVE)

Figure 320 SEM B.2.2, Indicator V039, V049 and V040 removed - Quality Analysis Tables

Investigations were made into a more discriminate solution by iteratively removing the most significantly cross loaded indicators iteratively.

- Outcomes — V038 New culture developed
- Outcomes — V040 Sustained implementation
- Management Knowledge — V105 Management continued to learn and participate
- Outcomes — V044 Developed a self-improving organisation
- Outcomes — V016 Performance enhanced

No increase in quality by AVE>0.5 criterion was found. Fornell – Larcker was slightly improved but only with all the above variables removed to V016.[206] With this, √(AVE) for Outcomes increased from 0.83 to 0.87, and its correlation with Enabling Employees decreased to 0.67. However Gof decreased to 0.41 from 0.46 as less of the variance in the model was explained, average R^2 dropped from 0.34to 0.26. See Figure 322, page 483.

[206] Just removing V016 with V038 and V040 did not have the same effect.

The removal of Indicators V039, V049, and V040 only was deemed suitable, explaining most variance and meeting quality criterion.

Cross loadings

	Advanced Methods	Enabl Employees	Extended VS	Mngmnt Knowledge	Momentum/ Regularity	Outcomes	Resources	Simple Methods
AM_V087_Just_In_Time_Manufacture	0.67	0.25	0.35	0.28	0.22	0.29	0.06	0.14
AM_V089_Total_Productive_Maintenance	0.63	0.22	0.11	0.25	0.18	0.04	0.12	0.44
AM_V094_Pull_Systems	0.79	0.36	0.23	0.41	0.28	0.29	0.04	0.24
AM_V095_Kanban	0.72	0.21	0.04	0.27	0.00	0.08	-0.10	0.27
EE_V041_Worker__Initiatives	0.30	0.87	0.46	0.63	0.57	0.70	0.36	0.59
EE_V048_Easy_for_suggestion/improvement	0.36	0.84	0.36	0.66	0.56	0.69	0.34	0.34
EE_V057_Involved_all_Staff	0.34	0.87	0.46	0.65	0.54	0.65	0.20	0.57
EVS_V100_Engaging_suppliers	0.36	0.40	0.87	0.36	0.24	0.40	0.11	0.24
EVS_V101_Engaging_customers	0.18	0.48	0.92	0.42	0.39	0.51	0.33	0.39
MK_V055_Mngmnt_had_exclnt_lean_knwld	0.46	0.55	0.34	0.70	0.23	0.41	0.25	0.41
MK_V067_Mgmt_understood_tools/_method	0.36	0.54	0.25	0.85	0.32	0.49	0.27	0.45
MK_V068_Mgmt_understood_as_a_new_cu	0.26	0.55	0.30	0.77	0.46	0.47	0.22	0.48
MK_V105_Mngmnt_contin._to_learn_and_p	0.39	0.75	0.39	0.76	0.57	0.62	0.33	0.42
MK_V106_Mgmt_established_lean_knowled	0.23	0.42	0.39	0.74	0.37	0.36	0.34	0.35
MR_V032_Momentum_Constant	0.22	0.47	0.26	0.44	0.78	0.51	0.17	0.12
MR_V072_Small_wins_prominent	0.13	0.51	0.28	0.36	0.75	0.57	0.24	0.21
MR_V078_Program/Structure/Regularity	0.26	0.49	0.28	0.38	0.72	0.50	0.29	0.39
OC_V016_Performance_Enhanced	0.29	0.71	0.49	0.51	0.64	0.90	0.24	0.32
OC_V017_Staff_Morale_Incr.	0.20	0.58	0.36	0.37	0.45	0.75	0.20	0.31
OC_V038_New_Cult_Developed	0.24	0.72	0.46	0.62	0.66	0.88	0.33	0.44
OC_V044_Developed_a_self-improving_org.	0.20	0.70	0.48	0.63	0.64	0.81	0.42	0.46
OC__V015_Competitive_Advantage	0.26	0.58	0.32	0.44	0.47	0.81	0.29	0.34
RC_V062_Staff_Capability	0.07	0.35	0.30	0.25	0.26	0.36	0.79	0.28
RC_V063_Technology_Capability	0.04	0.05	0.10	0.24	0.03	0.11	0.57	0.04
RC_V064_Management_Capability	0.07	0.33	0.15	0.37	0.28	0.28	0.81	0.31
RC_V066_Impl._Leader_Capability	-0.10	0.19	0.18	0.18	0.26	0.24	0.70	0.23
SM_V080_Standard_work_developed	0.30	0.47	0.30	0.41	0.25	0.35	0.22	0.72
SM_V091_5_Whys	0.33	0.38	0.03	0.30	0.15	0.20	0.11	0.74
SM_V092_Simple_problem_solving	0.14	0.42	0.26	0.47	0.16	0.35	0.33	0.78
SM_V098_Visual_Systems	0.39	0.58	0.42	0.56	0.38	0.48	0.28	0.86
SM_V099_Root_Cause_Analysis	0.21	0.35	0.27	0.33	0.20	0.30	0.28	0.80

Variables must load their consruct higher than any other construct. Values > 0.6 highlighted

Figure 321 Cross loadings, SEM B.2.2, Indicator V039, V049 and V040 removed - Quality Analysis Tables

Quality Overview

	AVE	Composite Reliability	Cronbachs Alpha	Redund-ancy	R Square	Communality
Significance criteria	*>0.5*	*>0.6**	*>0.7***		*>0.1*	
Minimum Observed	0.49	0.80	0.62		0.13	0.49
Advanced Methods	0.49	0.80	0.67	0.09	0.18	0.49
Enabl Employees	0.74	0.89	0.82	0.32	0.43	0.74
ExtendedVS	0.80	0.89	0.75	0.13	0.16	0.80
Management knowledge	0.64	0.87	0.81	N/A	N/A	0.64
Momentum/Regularity	0.57	0.80	0.62	0.11	0.20	0.57
Outcomes	0.76	0.86	0.68	0.01	0.47	0.76
Resources	0.52	0.81	0.70	0.06	0.13	0.52
Simple Methods	0.61	0.89	0.84	0.16	0.28	0.61

**Composite Reliability >0.6 for exploratory research or >0.7 for developed research.*
***Cronbachs Alpha is included for reference Composite reliability is prefered over Conbach's Alpha for PLS-SEM. Refer: Hair J. F. 2011, PLS-SEM: Indeed a Silver*

Goodness of fit Calculation

Avg R^2	*Avg Com.*
0.26	*0.64*
Gof =	*0.41*

Fornell - Larcker Criterion (Fornell & Larcker, 1981)

	Advanced Methods	Enabl Employees	Extended VS	Mngmnt Knowledge	Momentum/ Regularity	Outcomes	Resources	Simple Methods
Advanced Methods	**0.70**							
Enabl Employees	0.40	**0.86**						
ExtendedVS	0.30	0.49	**0.89**					
Management knowledge	0.42	0.66	0.40	**0.80**				
Momentum/Regularity	0.28	0.65	0.36	0.45	**0.75**			
Outcomes	0.27	0.67	0.39	0.39	0.53	**0.87**		
Resources	0.06	0.35	0.24	0.36	0.31	0.28	**0.72**	
Simple Methods	0.35	0.57	0.35	0.53	0.31	0.37	0.32	**0.78**

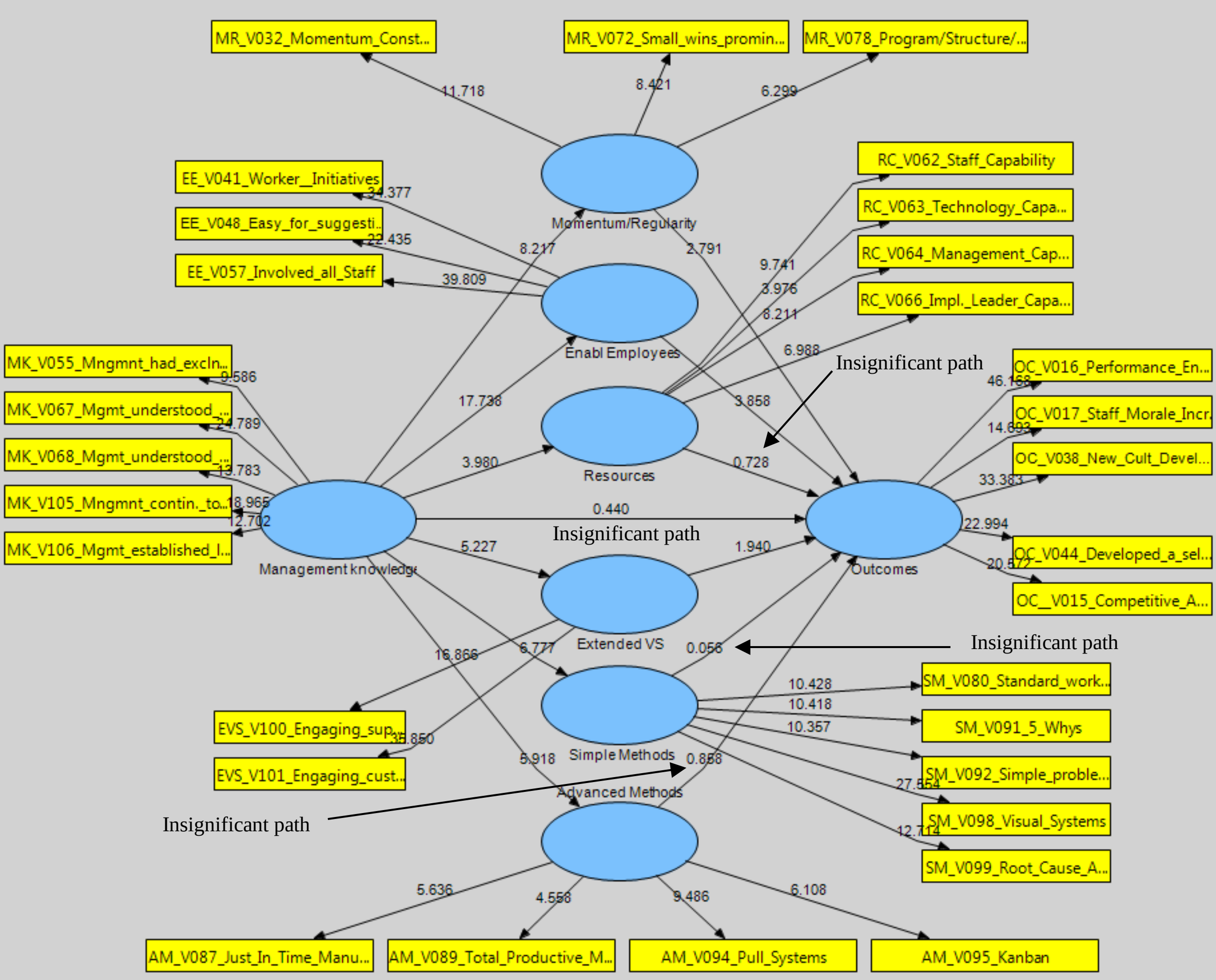
Cross loadings

	Advanced Methods	Enabl Employees	Extended VS	Mngmnt Knowledge	Momentum/ Regularity	Outcomes	Resources	Simple Methods
AM_V087_Just_In_Time_Manufacture	0.68	0.26	0.37	0.27	0.23	0.29	0.07	0.14
AM_V089_Total_Productive_Maintenance	0.62	0.22	0.12	0.26	0.18	-0.02	0.13	0.44
AM_V094_Pull_Systems	0.79	0.37	0.24	0.37	0.30	0.28	0.04	0.24
AM_V095_Kanban	0.71	0.21	0.05	0.26	0.00	0.08	-0.09	0.27
EE_V041_Worker__Initiatives	0.31	0.86	0.46	0.54	0.58	0.57	0.36	0.58
EE_V048_Easy_for_suggestion/improvement	0.37	0.85	0.36	0.59	0.56	0.64	0.34	0.34
EE_V057_Involved_all_Staff	0.34	0.86	0.46	0.56	0.54	0.50	0.19	0.57
EVS_V100_Engaging_suppliers	0.37	0.40	0.88	0.34	0.24	0.33	0.11	0.23
EVS_V101_Engaging_customers	0.18	0.47	0.90	0.38	0.39	0.36	0.32	0.39
MK_V055_Mngmnt_had_exclnt_lean_knwld	0.47	0.55	0.35	0.75	0.25	0.32	0.26	0.41
MK_V067_Mgmt_understood_tools/_method	0.37	0.55	0.26	0.88	0.34	0.43	0.29	0.45
MK_V068_Mgmt_understood_as_a_new_cu	0.26	0.55	0.30	0.76	0.46	0.30	0.23	0.48
MK_V106_Mgmt_established_lean_knowled	0.23	0.43	0.38	0.79	0.38	0.18	0.36	0.35
MR_V032_Momentum_Constant	0.23	0.48	0.26	0.42	0.80	0.39	0.18	0.12
MR_V072_Small_wins_prominent	0.13	0.51	0.28	0.25	0.72	0.40	0.23	0.21
MR_V078_Program/Structure/Regularity	0.27	0.49	0.28	0.33	0.74	0.40	0.30	0.39
OC_V017_Staff_Morale_Incr.	0.22	0.59	0.37	0.30	0.46	0.88	0.21	0.31
OC__V015_Competitive_Advantage	0.25	0.57	0.31	0.38	0.45	0.86	0.28	0.33
RC_V062_Staff_Capability	0.08	0.35	0.30	0.23	0.26	0.23	0.75	0.29
RC_V063_Technology_Capability	0.05	0.06	0.10	0.29	0.03	0.04	0.60	0.04
RC_V064_Management_Capability	0.09	0.34	0.14	0.34	0.30	0.28	0.83	0.31
RC_V066_Impl._Leader_Capability	-0.10	0.20	0.17	0.14	0.26	0.23	0.69	0.23
SM_V080_Standard_work_developed	0.30	0.46	0.30	0.34	0.25	0.32	0.22	0.71
SM_V091_5_Whys	0.33	0.38	0.04	0.30	0.15	0.16	0.11	0.75
SM_V092_Simple_problem_solving	0.14	0.41	0.26	0.49	0.16	0.25	0.33	0.79
SM_V098_Visual_Systems	0.39	0.57	0.41	0.52	0.39	0.40	0.27	0.86
SM_V099_Root_Cause_Analysis	0.20	0.35	0.26	0.36	0.21	0.23	0.27	0.80

Figure 322 reference quality tables for fully discriminant solution

SEM B.2.2 Path Significance - Bootstrapping

Internal path significance of SEM B.2.2 was investigated by bootstrapping. Individual sign changes were allowed and the model was bootstrapped 5000 times.



	Original Sample	Sample Mean	Standard Deviation	Standard Error	T Statistics	p -value (Significance)
Advanced Methods -> Outcomes	-0.05	-0.08	0.06	0.06	0.86	0.39369
Enabl Employees -> Outcomes	0.52	0.51	0.13	0.13	3.86	0.00023
Extended VS -> Outcomes	0.14	0.14	0.07	0.07	1.94	0.05598
Management knowledge -> Advanced Metho	0.45	0.48	0.08	0.08	5.92	0.00000
Management knowledge -> Enabl Employees	0.75	0.76	0.04	0.04	17.74	0.00000
Management knowledge -> Extended VS	0.44	0.45	0.08	0.08	5.23	0.00000
Management knowledge -> Momentum/Regu	0.52	0.54	0.06	0.06	8.22	0.00000
Management Knowledge -> Outcomes	0.03	0.09	0.07	0.07	0.44	0.66123
Management knowledge -> Resources	0.37	0.39	0.09	0.09	3.98	0.00015
Management knowledge -> Simple Methods	0.55	0.57	0.08	0.08	6.78	0.00000
Momentum/Regularity -> Outcomes	0.30	0.31	0.11	0.11	2.79	0.00660
Resources -> Outcomes	0.04	0.07	0.06	0.06	0.73	0.46867
Simple Methods -> Outcomes	0.00	-0.08	0.07	0.07	0.06	0.95541

Figure 323 SEM B.2.2 bootstrapped (5000 times, individual sign changes allowed) model showing t-statistics: t-values are 1.65 for 10% (α=0.1), 1.96 for 5% (α =0.05), 2.58 for 1% (α =0.01).

The following paths were found insignificant (well beyond a low acceptance level α of 0.1):

Resources -> Outcomes	p=0.50	β=0.47
Advanced Methods -> Outcomes	p=0.40	β=-0.08
Simple Methods -> Outcomes	p=0.96	β=-0.004
Management Knowledge-> Outcomes	p=0.66	β=0.03

Removing weakest paths and testing them in turn did not raise the significance of either path to α of 0.1 let alone 0.05. SEM B2 was modified: the paths Resources -> Outcomes, Advanced Methods -> Outcomes and

Simple Methods -> Outcomes were removed. A final quality analysis shows criteria well met (Figure 324) and the resultant model is presented as SEM B.2.3 (Figure 325).

Quality Overview

	AVE	Composite Reliability	Cronbachs Alpha	Redund-ancy	R Square	Communality
Significance criteria	*>0.5*	*>0.6**	*>0.7***		*>0.1*	
Minimum Observed	0.50	0.80	0.62		0.15	0.50
			*See***			
Advanced Methods	0.50	0.80	0.67	0.09	0.20	0.50
Enabl Employees	0.74	0.89	0.82	0.42	0.56	0.74
ExtendedVS	0.80	0.89	0.75	0.15	0.19	0.80
Management Knowledge	0.59	0.88	0.82	N/A	N/A	0.59
Momentum/Regularity	0.57	0.80	0.62	0.16	0.27	0.57
Outcomes	0.69	0.92	0.89	0.39	0.71	0.69
Resources	0.52	0.81	0.70	0.07	0.15	0.52
Simple Methods	0.61	0.89	0.84	0.17	0.30	0.61

**Composite Reliability >0.6 for exploratory research or >0.7 for developed research.*
***Cronbachs Alpha is included for reference. Composite reliability is prefered over Conbach's Alpha for PLS-SEM. Refer: Hair J. F. 2011, PLS-SEM: Indeed a Silver Bullet*

Goodness of fit Calculation

Avg R^2	***Avg Com.***
0.34	*0.63*
Gof =	*0.46*

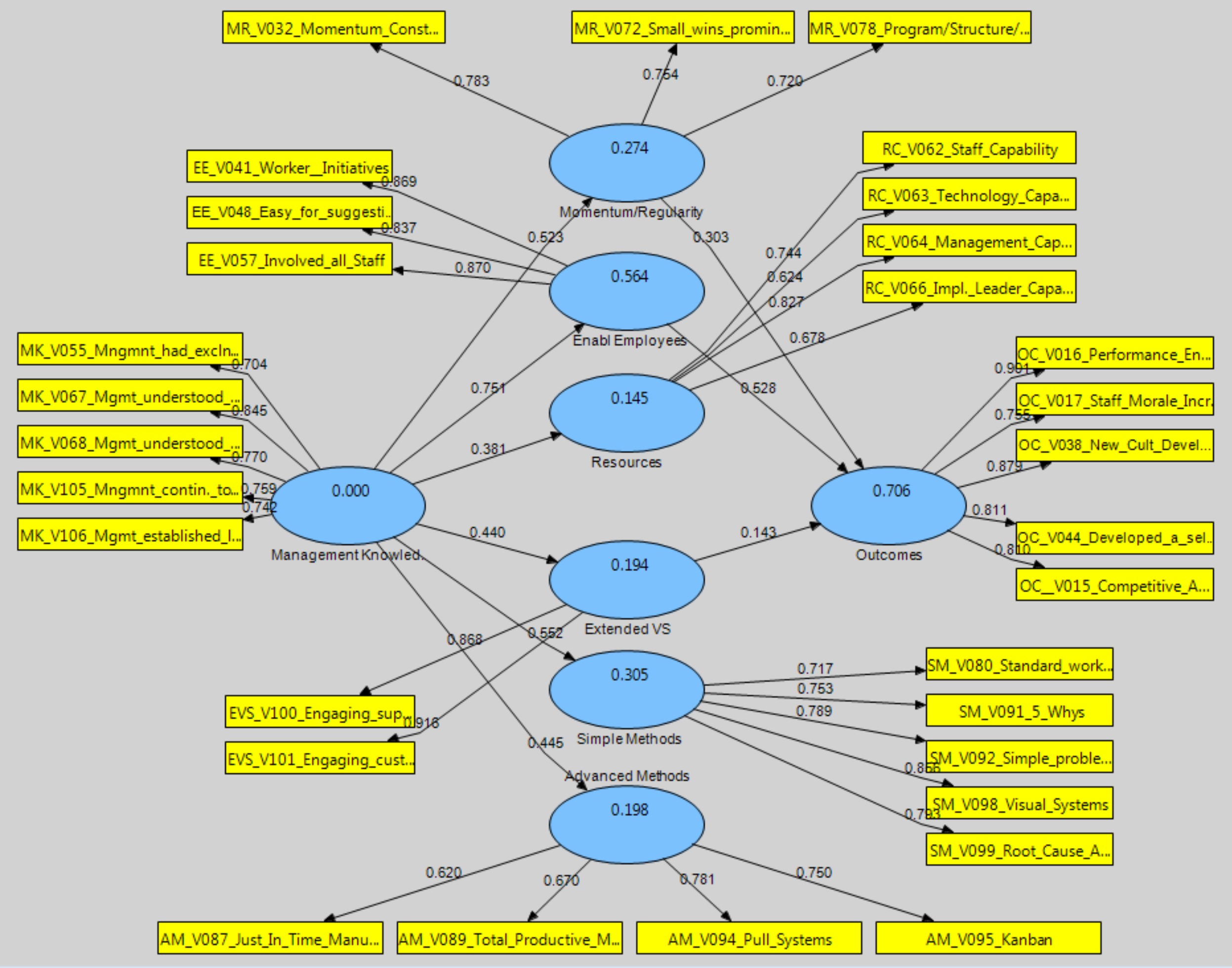
Gof = SQRT((Avg R^2)(Avg Com.))*
Gof > 0.31 recommended

Fornell - Larcker Criterion (Fornell & Larcker, 1981)

	Advanced Methods	Enabl Employees	Extended VS	Mngmnt Knowledge	Momentum/ Regularity	Outcomes	Resources	Simple Methods
Advanced Methods	**0.71**							
Enabl Employees	0.38	**0.86**						
ExtendedVS	0.27	0.50	**0.89**					
Management Knowledge	0.44	0.75	0.44	**0.77**				
Momentum/Regularity	0.26	0.65	0.36	0.52	**0.75**			
Outcomes	0.26	0.80	0.52	0.63	0.70	**0.83**		
Resources	0.05	0.33	0.24	0.38	0.29	0.34	**0.72**	
Simple Methods	0.37	0.58	0.35	0.55	0.31	0.45	0.31	**0.78**

Latent Variable Correlations compared with √(AVE), i.e. check √(AVE) >factor loading, Bold = √(AVE)

Figure 324 SEM B.2.3 model quality tables (SEMB.2.3 excludes V039, from Momentum/Regularity, V040 from Outcomes and V049 from Enabling Employees).

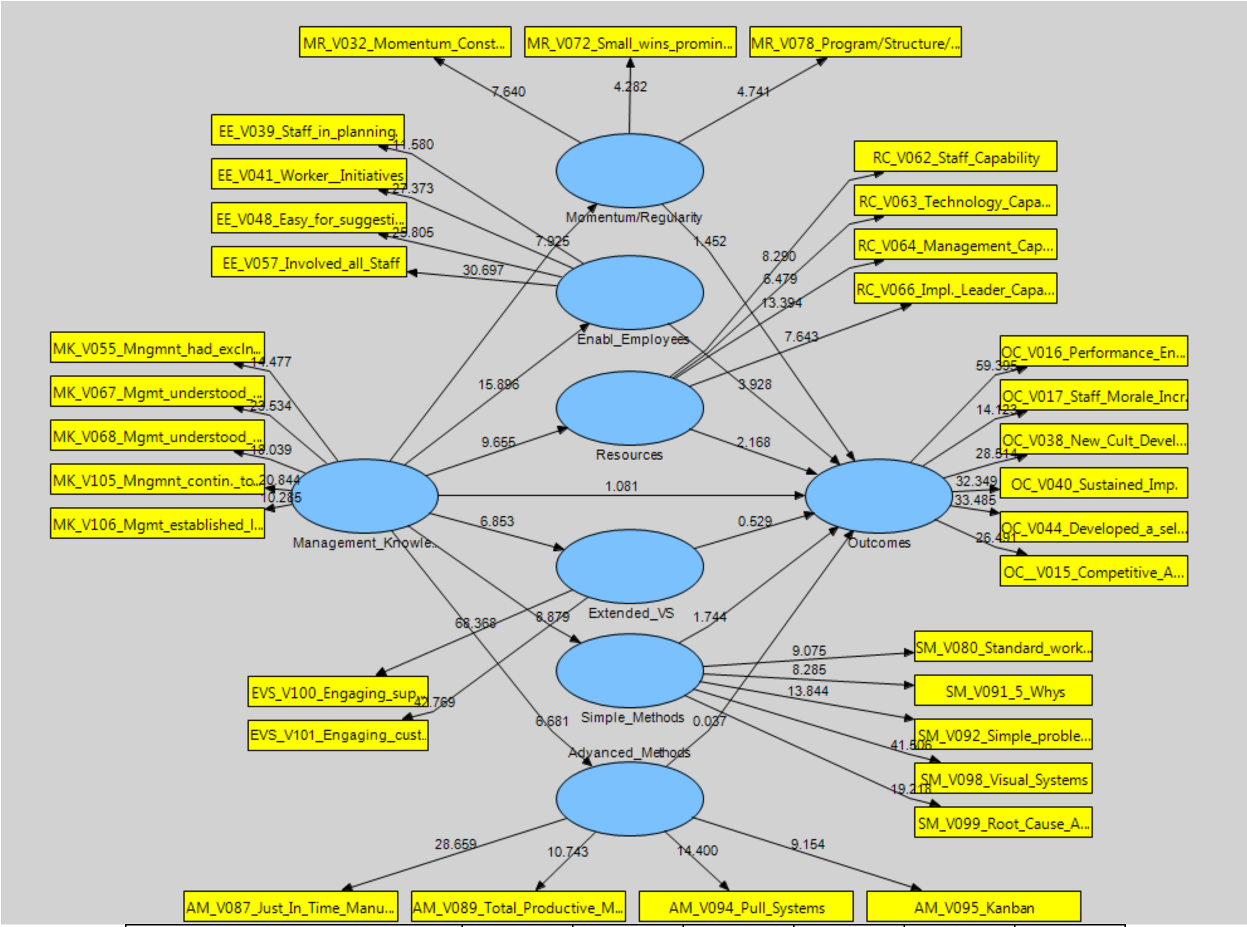


	Original Sample	Sample Mean	Standard Deviation	Standard Error	T Statistics	p -value (Significance)
Enabl Employees -> Outcomes	0.53	0.52	0.10	0.10	5.12	0.00000
Extended VS -> Outcomes	0.14	0.15	0.07	0.07	2.02	0.04684
Management Knowledge -> Advanced Met	0.44	0.47	0.07	0.07	6.03	0.00000
Management Knowledge -> Enabl Employe	0.75	0.75	0.04	0.04	17.48	0.00000
Management Knowledge -> Extended V	0.44	0.45	0.08	0.08	5.43	0.00000
Management Knowledge -> Momentum/Regu	0.52	0.53	0.06	0.06	8.14	0.00000
Management Knowledge -> Resources	0.38	0.41	0.09	0.09	4.31	0.00005
Management Knowledge -> Simple Metho	0.55	0.57	0.08	0.08	7.03	0.00000
Momentum/Regularity -> Outcomes	0.30	0.32	0.10	0.10	3.10	0.00267

Figure 325 SEM B.2.3 resultant model of Lean Knowledge-Based View for small business case (11-100 employees). Extended VS->Outcomes significant to p<0.05, Momentum/Regularity to outcomes significant to p<0.003, all others p<0.0001 (393 lean and lean six sigma cases, 90%+ complete, bootstrapped 5000 times, individual sign changes allowed).

SEM B.4 – Low Variety High Volume

The resultant bootstrapped model of SEM B.4 is shown below.



	Original Sample	Sample Mean	Standard Deviation	Standard Error	T Statistics	p -value (Significance)
Advanced_Methods->Outcomes	0.0022	0.0811	0.0609	0.0609	0.0366	0.97088
Enabl_Employees->Outcomes	0.4372	0.4316	0.1113	0.1113	3.9278	0.00016
Extended_VS->Outcomes	0.0263	0.0632	0.0497	0.0497	0.5288	0.59819
Management_Knowledge->Advanced_Metho	0.5025	0.5089	0.0752	0.0752	6.6806	0.00000
Management_Knowledge->Enabl_Employees	0.7293	0.732	0.0459	0.0459	15.8962	0.00000
Management_Knowledge->Extended_VS	0.4941	0.4962	0.0721	0.0721	6.8526	0.00000
Management_Knowledge->Momentum/Regu	0.524	0.5407	0.0661	0.0661	7.9249	0.00000
Management_Knowledge->Outcomes	0.0838	0.1095	0.0775	0.0775	1.0811	0.28242
Management_Knowledge->Resources	0.621	0.626	0.0643	0.0643	9.6548	0.00000
Management_Knowledge->Simple_Methods	0.6218	0.6252	0.07	0.07	8.8788	0.00000
Momentum/Regularity->Outcomes	0.1098	0.1249	0.0757	0.0757	1.4515	0.14997
Resources->Outcomes	0.1699	0.1792	0.0784	0.0784	2.1681	0.03268
Simple_Methods->Outcomes	0.1578	0.1711	0.0905	0.0905	1.7444	0.08436

Figure 326 SEM B.4.1 bootstrapped (5000 times, individual sign changes allowed, V049 removed) model showing t-statistics: t-values are 1.65 for 10% (α=0.1), 1.96 for 5% (α =0.05), 2.58 for 1% (α =0.01).

SEM B Analysis Halted

Analysis stopped with SEM B.4.1. It was realised that the effects of advanced methods (including JIT) were not being recognised as significant in this model. A new model was developed. See discussion under SEM B Intermediate Exploration (Constructs and Model), p. 244.

13.2.5 Individual Variable Assessments for Extreme Skew

The response “not at all” was over represented in the following variables:

- External Support (V043)
- Fear as a Motivator (V071)
- A3 management or Nemawashi or Catchball Process (V088)

The histograms of these variables are presented below, Figure 327, Figure 328, and Figure 329. Correlations of the variables themselves are compared collectively with key output/response variables Figure 330 (p. 489).

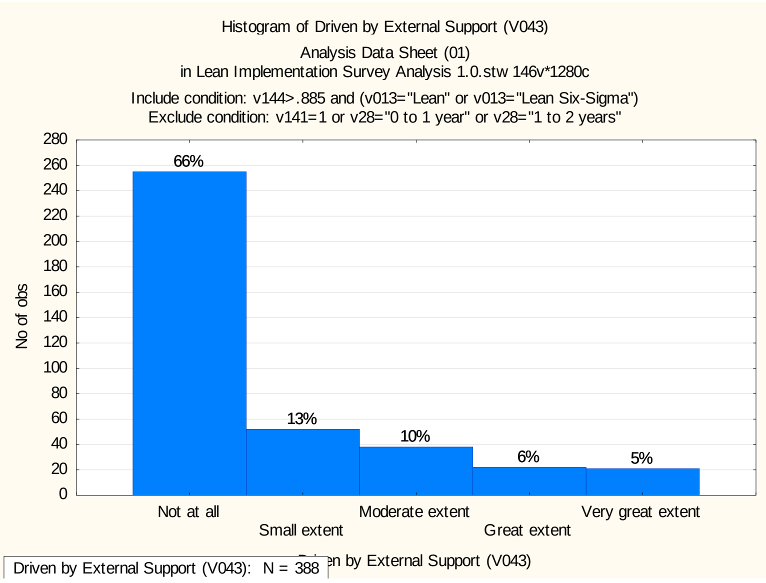


Figure 327 External Support (V043) - Histogram showing over representation of “not at all”

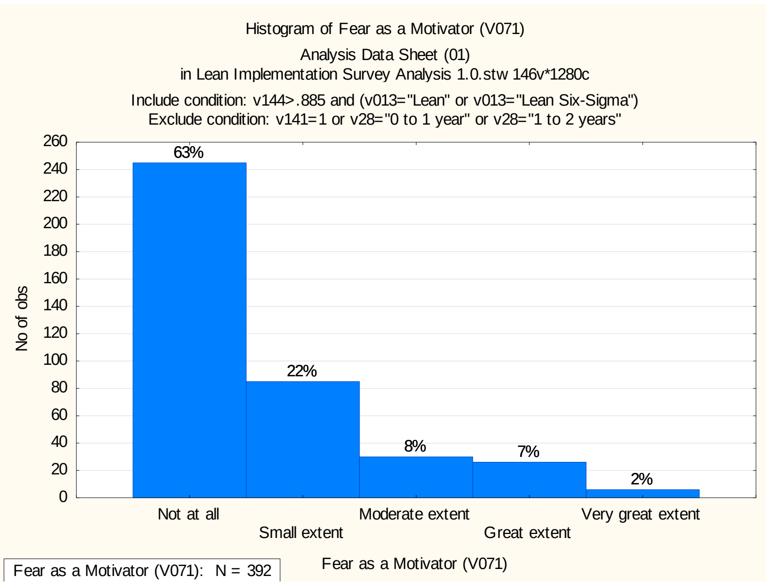


Figure 328 Fear as a Motivator (V071) - Histogram showing over representation of “not at all”

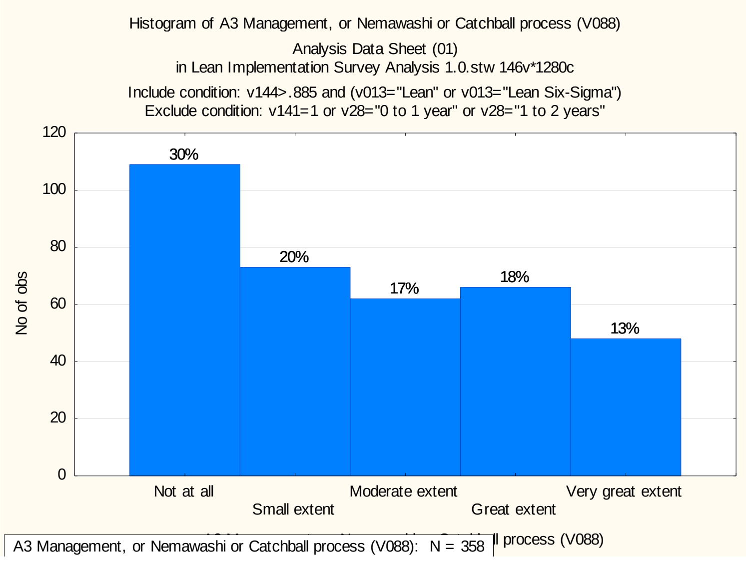


Figure 329 The use of A3 management or Nemawashi or Catchball Process (V088) - Histogram showing over representation of "not at all"

	Driven by External Support (V043)		Fear as a Motivator (V071)		A3 Management, or Nemawashi or Catchball process (V088)	
	All codes	Excluded V043="Not at all"	All codes	Excluded V071="Not at all"	All codes	Excluded V088="Not at all"
Developed Self-improving Org. (V044)	.0056 N=386 p=.913	.0777 N=131 p=.378	.0354 N=390 p=.485	-.0014 N=147 p=.987	.2006 N=357 p=.000	.2084 N=248 p=.001
Performance Enhanced (V016)	.0019 N=386 p=.970	.1827 N=132 p=.036	.0235 N=390 p=.643	-.1373 N=146 p=.098	.1381 N=356 p=.009	.1107 N=248 p=.082
New Cult Developed (V038)	-.0601 N=385 p=.239	.0742 N=132 p=.398	.0211 N=389 p=.679	-.0939 N=145 p=.261	.2325 N=355 p=.000	.1624 N=248 p=.010
Sustained Imp. (V040)	-.0688 N=376 p=.183	-.0737 N=130 p=.405	-.0075 N=379 p=.884	-.0128 N=143 p=.879	.1342 N=347 p=.012	.2008 N=242 p=.002
Mgt. Press still Needed (V061)	.0890 N=369 p=.088	.0867 N=127 p=.332	.2202 N=372 p=.000	.1644 N=140 p=.052	.0665 N=340 p=.221	-.0016 N=237 p=.980
New staff identity devel. (V074)	.0668 N=381 p=.193	-.0247 N=128 p=.782	.1129 N=385 p=.027	.1373 N=146 p=.099	.1468 N=352 p=.006	.0668 N=244 p=.298
Employees resisted change (V102)	.0706 N=388 p=.165	-.0198 N=133 p=.821	.1860 N=392 p=.000	.0606 N=147 p=.466	.1301 N=358 p=.014	.0305 N=249 p=.632
Staff Morale Incr. (V017)	.0044 N=386 p=.931	-.0134 N=133 p=.878	.0029 N=390 p=.954	-.0145 N=146 p=.862	.1398 N=358 p=.008	.1543 N=249 p=.015

Marked correlations are significant at p < .05: Include condition: v144>.885 and (v013="Lean" or v013="Lean Six-Sigma") and V133="Used Consultant". Exclude condition: v141=1 or v28="0 to 1 year" or v28="1 to 2 years"

Figure 330 Driven by External Support (V043), Fear as a Motivator (V071), A3 management or Nemawashi or Catchball Process (V088) – Correlation to key output/response variables with and without "not at all" responses.

Driven by External Support

Driven by External Support (V043) refers primarily to financial support provided to support and motivate an organisation to implement lean. Referring to Figure 330 (p. 489) it can be seen that removing “not at all” responses from Driven by External Support (V043) brought forth one correlation out of the selected response variables. The correlation was with Performance Enhancement (V016) but was weak (r=0.18, p=0.038, N=132) as seen in plots Figure 331 (p. 490), means plot for performance enhanced were not dissimilar to comparison with other response variables e.g. Developed Self-improving Org. (V044) (Figure 332, p. 491).

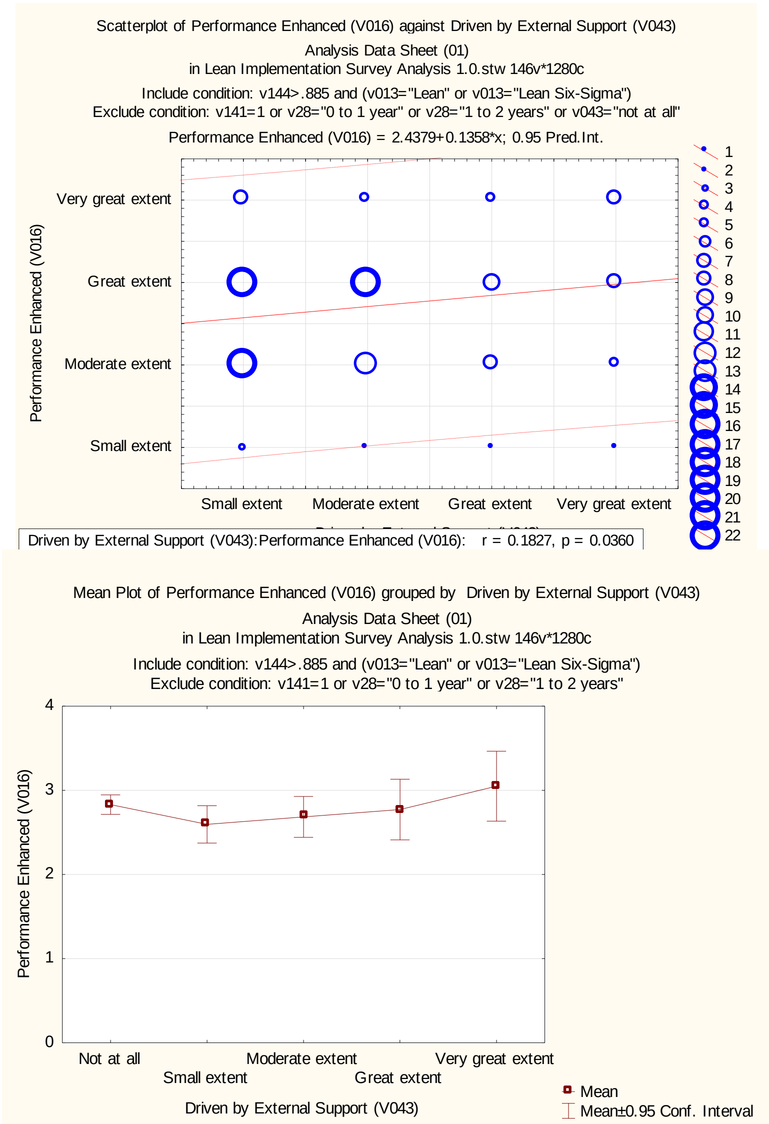


Figure 331 Driven by External Support (V043) vs. Performance Enhanced (V016) – Scatter and means plots showing weak correlation (95% CI)

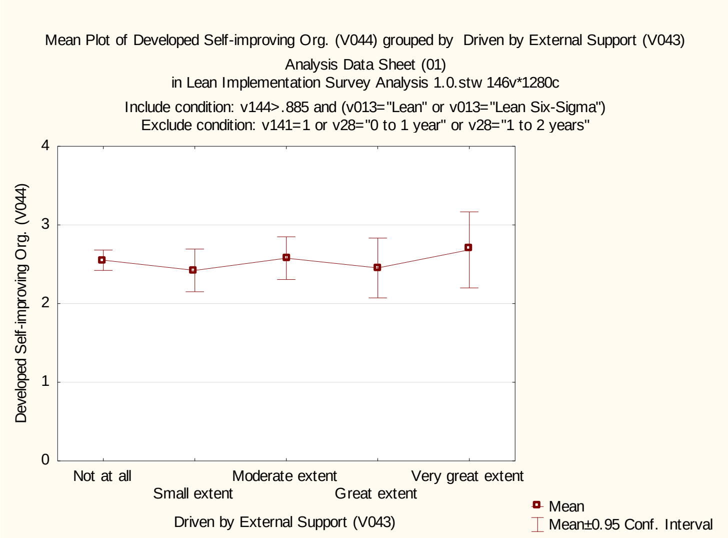


Figure 332 Driven by External Support (V043) vs. Developed Self-improving Org. (V044) –Means plots showing weak correlation (95% CI)

Fear as a Motivator

Fear as a motivator (V071) came from the question "To what extent was fear was used as a motivator (e.g. loss of jobs or income)". This variable showed no particularly significant correlations (Figure 330, p. 489). A borderline correlation was seen with V061, management pressure still required to maintain the implementation and V102 employees resisted change. New staff identity (V074) was highlighted due to low p but effect r was negligible at 0.1 (even for sufficiently large n~390). The weakness of these correlations are further seen when excluding the "Not at all" cases". The correlation table is seen in full, Figure 330, p. 489; and in an extracted form in Figure 333.

	Fear as a Motivator (V071)	
	All codes	Excluded V071="Not at all"
Performance Enhanced (V016)	.0235 N=390 p=.643	-.1373 N=146 p=.098
Mgt. Press still Needed (V061)	.2202 N=372 p=.000	.1644 N=140 p=.052
New staff identity devel. (V074)	.1129 N=385 p=.027	.1373 N=146 p=.099
Employees resisted change (V102)	.1860 N=392 p=.000	.0606 N=147 p=.466

Figure 333 Fear as a Motivator (V071), – Correlation to key output/response variables with and without "not at all" responses. Extracted from full table, Figure 330.

Means plots (95% CI) grouped by Fear as a Motivator (V071) confirm the weakness of correlation with performance enhancement (V016) and staff identity development (V074) as well as the lack of general trend. Plotting for Management Pressure still Needed (V061) by Fear as a Motivator (V071) however does show general trend along with Employees resisted change (V102) which showed correlation and general trend strength from "not at all" to "moderate extent" (Figure 336and Figure 337). Using fear tactics is not shown to improve performance. Conversely, the use of fear tactics (e.g. loss of job or income) is associated with staff resistance to the lean change and an increase with management pressure being required. Job security is referenced as important during lean implementation (J. P. Womack & Jones, 2003), e.g. for staff to cooperate and not resist change. This confidence should be to the extent that an employee would *improve themselves* out of a job with confidence they would be relocated.

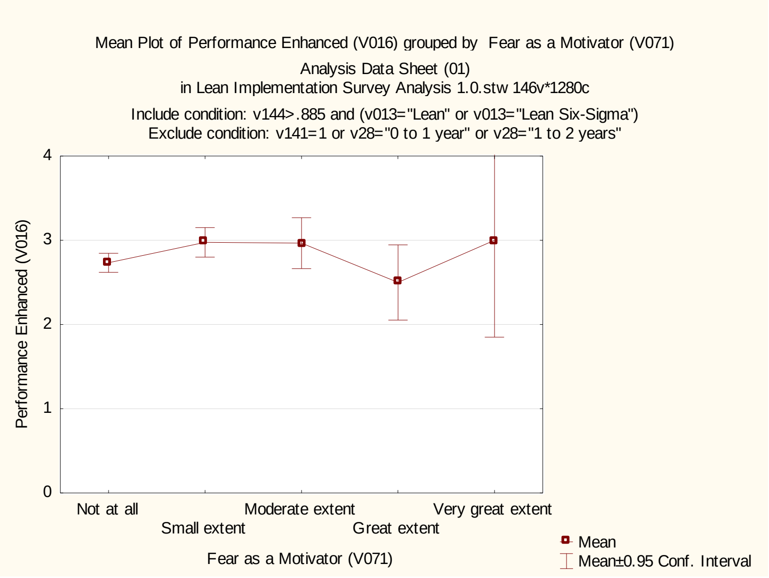


Figure 334 Performance Enhanced (V016) by Fear as a Motivator (V071) – Means plot shows negligible correlation and general trend (95% CI)

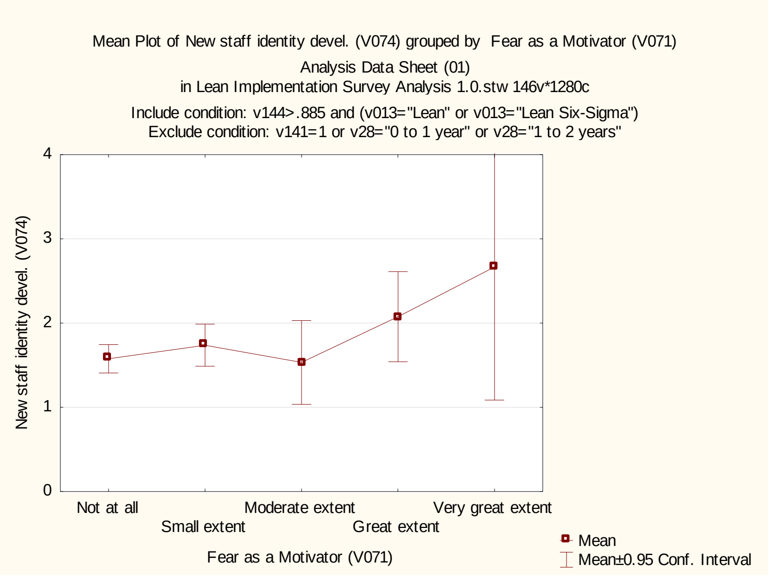


Figure 335 New staff identity developed (V074) by Fear as a Motivator (V071) – Means plot shows negligible correlation and general trend (95% CI)

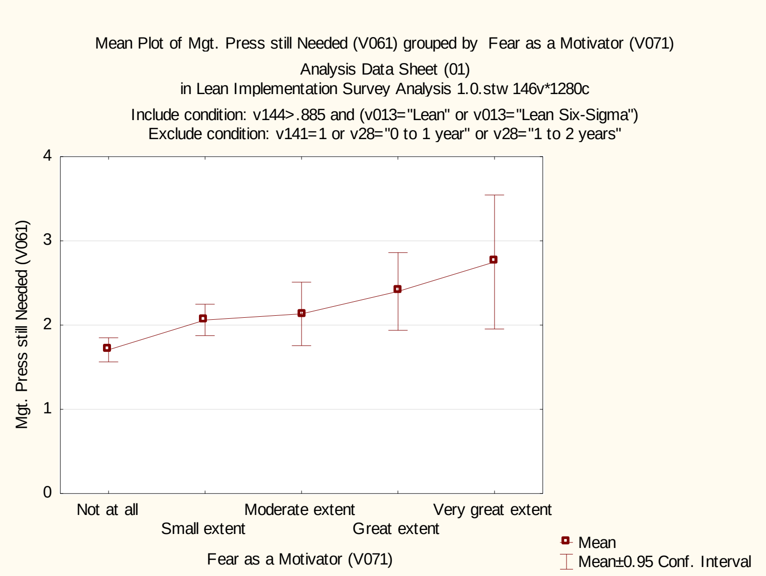


Figure 336 Management Pressure still Needed (V061) by Fear as a Motivator (V071) – Means plot shows border line correlation and general trend (95% CI)

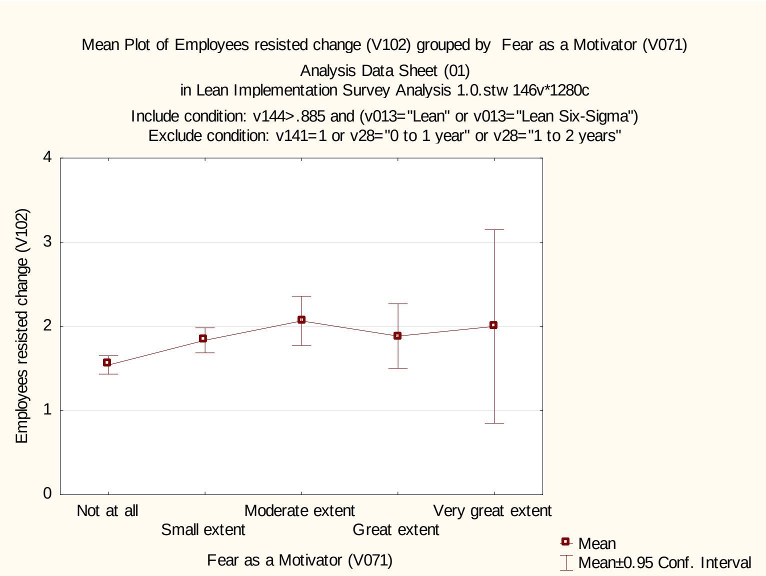


Figure 337 Employees resisted change (V102) by Fear as a Motivator (V071) – Means plot shows border line correlation and general trend from “not at all” to moderate extent” (95% CI)

A3 management or Nemawashi or Catchball Process

“Not at all” was slightly over represented in A3 management or Nemawashi or Catchball Process (V088, Figure 329, p. 489). This and similar “flattened” distributions also are clearly non normal (“extreme kurtosis” to say the least). But not as serious as an over representation at one end of the scale. Figure 330 (p. 489) shows that the correlations were comparable with or without the “not at all” responses especially considering decreased sample size (n). The variable can be covered by overall analysis without concern.

13.2.6 Consultant Variable Analysis and Development of Method to Address Ambiguity

The following chart was used to address ambiguity in consultant use questions. Result was a “consultant use” (V133) field inferred from the variables 035, 065 and 073. This could be used to exclude no consultant cases from analysis when appropriate.

Extent Impl. By Consultant (V035)	**Consultant Capability** (See *) **(V065)**	**Consultant As Coach (V073)**	**Inferred Meaning**	**Comment**	**Effect On Main Analysis**	**Treatment For Analysis**
Not at all	None/not at all	Some extent	Consultant used for advice but not direct involvement in carrying out.	Assume if advice of consultant seen as useless and consultant was not involved in the implementation. Effect on implementation is little in this case so results/outcomes should not be affected.	Possible error in checking the effect of consultant capability on success and if looking at mean value of capability e.g. mean capability by country.	Developed "consultant use" (V133) field inferred from the variables 035, 065 and 073 (see also**). Exclude no consultant cases from an analysis to ensure actually testing level of capability and not overly weighted by cases where consultant were not used.
		Not at all Or Blank	No consultant used			
	Blank***	Not at all Or Blank	No consultant used	Logically most of these blank cases		As above remove "no consultant" cases from analysis to see if variable rises in effect.
		Some extent	No answer for integrity sake i.e. participant answering was the consultant and felt it inappropriate to self-report on ability or don't know	Assumed inferred by role = "consultant/advisor" or similar "other " role	Assumed of no significant effect on the analysis	
			Any blanks could also imply Don't know the answer	For skipping the question – there was a "don't know option" so probable only a small percentage	Assumed not of a great effect on the analysis.	
	Some level of capability	Some extent	Consultant used for advice but not direct involvement in carrying out.	No ambiguity	No error into analysis	
Some Extent	Blank***		Left blank for integrity		No significant error, only small number of cases – not major issue	None required
	Not at all		Not capable	No ambiguity/error in analysis	Associations could be important	Eventually check for association
Notes	*note this is very subjective and could be directly affected by the level of success as would other capability measures – compare any correlation to success/failure with capability **Cases excluded for checking effect of capability can be re-included if consultant variables are found not to be significant.					
Main Solutions	Do analysis with added (inferred) Consultant Use (V133) variable to filter out where no consultant was used. Check any difference with or without.					
Additional Caution	Be careful with mean calculations on consultants use as coach and capability use filter out no consultant used. Consultants may self-report high capability for themselves. Consultant capability is not only very subjective but also dependent on outcome (e.g. if people don't know what true lean is how can they rate competence of a consultant – maybe he is eloquent and good at tools but not org. development, also if project goes well they will think consultant is great). <<<future work look at what consultant did/didn't do>>					

Figure 338 Consultant use: table analysis used for addressing of ambiguity.

14. Appendix 3—Survey Questions

14.1 Questions by Conceptual Framework

The following tables chart all questions against the tentative overview conceptual framework (p. 134) as discussed therein.

14.1.1 Experiment One—Questions by Overview Conceptual Framework

	Situational Variables and General Demographic	Planned Change	Emergent Change	Outcomes	Process	Culture	Leadership	Knowledge & Capability	Strategy and Vision	Goals,Regularity and Review	Journey View	Fostering Behaviours or Resistance	Guiding Coalition	Communication Process	Embed Culture First (Small Wins)	Maintaining Change	Identity with Growth mindset	Supporting the Habits	Method Selection	Goals,Regularity and Review	Internal & External Resources	Lean 5 Principles (included in process)	Other
Case ID (V001)	X																						
Completed (V002)	X																						
Sample Groups (V003)	X																						
Sample Group (other) (V004)	X																						
Gender (V005)	X																						
Country (V006)	X																						
Country (other) (V007)	X																						
Training (V008)-(V028)								X															
Industry - other (V028)								X															
Role (V029)								X															
Role - other (V030)								X															
Business Staff (V031)	X																						
Work Experience (V032)								X															
Lean - Familiarity (V033)								X															
TOC - Familiarity (V034)								X															
Agile Mfg. - Familiarity (V035)								X															
Agile IT - Familiarity (V036)								X															
Six Sigma - Familiarity (V037)								X															
TPS - Familiarity (V038)								X															
Quality Sys - Familiarity (V039)								X															
Cost Acc. - Familiarity (V040)								X															
Reasons not pursued Lean knowledge (V041)								X															X
Reasons pursued Lean knowledge (V042)								X															X
Lean - Impl. (V043)								X															
Agile Mfg. - Impl. (V044)								X															
Agile IT - Impl. (V045)								X															
TOC - Impl. (V046)								X															
Quality Sys - Impl. (V047)								X															
Six-Sigma - Impl. (V048)								X															
Lean SS - Impl. (V049)								X															
Repacking of JIT/Qual. Sys (V050)																							X
Tools, processes (V051)					X																		
Process Eng. (V052)					X																		
Waste Elimin. (V053)					X																		
Train & Empower (V054)			X			X																	
Fragile/ Unbuffered (V055)																							X
New Systems/Ways (V056)					X																		

	Situational Variables and General Demographic	Planned Change	Emergent Change	Outcomes	Process	Culture	Leadership	Knowledge & Capability	Strategy and Vision	Goals,Regularity and Review	Journey View	Fostering Behaviours or Resistance	Guiding Coalition	Communication Process	Embed Culture First (Small Wins)	Maintaining Change	Identity with Growth mindset	Supporting the Habits	Method Selection	Goals,Regularity and Review	Internal & External Resources	Lean 5 Principles (included in process)	Other
Respecting People (V057)			X			X																	
Philos. / Strategy (V058)			X	X		X	X																
Needs regularity and focus (V059)																X							X
New label - Indus. Eng. (V060)					X																		
Comment (V061)								X															
Comp. Advantage (V062)				X																			
Commment (V063)																							
The extent that a manager understands Lean is critical for							X	X															
In a small organisations management's understanding is							X	X															
Comment - Management Knowledge crucial (V066)							X	X															
Large impact (V067)					X										X	X			X				
Best Methods (V068)					X														X				
Comm. Process (V069)			X			X								X									
Staff Identity (V070)			X														X						
Small and regular (V071)						X									X	X							
Key Staff Only (V072)																							
Mgmt Force (V073)		X														X							
Technology (V074)					X																		
Simple Techniques (V075)						X										X							
Implementation Focus Comments (V076)																							X
Adv. Sys, MRP ERP (V077)																							
Alignment (V078)						X																	
5 S System (V079)					X																		
Just In Time (V080)					X																		
A3 Mgmt or Nemawashi (V081)					X	X																	
TPM (V082)																							
Kaizen Events (V083)																							
5 Whys (V084)					X																		
Define Value (V085)																						X	
Pull Systems (V086)																						X	
Kanban (V087)					X																		
Cont. Improvement Cult. (V088)						X																	
Dev. Flow (V089)																						X	
VSM (V090)																						X	
Visual Systems (V091)					X													X					
Become Learning Org. (V092)			X	X		X																	
Root Cause Anal. (V093)					X																		
Lean/ Flow Accounting (V094)					X																		
Standard Work (V095)					X													X					
Final Comment (V096)																							

Figure 339 Experiment One—questions by overview conceptual framework

14.1.2 Experiment Two—Questions by Overview Conceptual Framework

	Situational Variables and General Demographic	Planned Change	Emergent Change	Outcomes	Process	Culture	Leadership	Knowledge & Capability	Strategy and Vision	Goals Regularity and review	Journey View	Fostering Behaviours or Resistance	Guiding Coalition	Communication Process	Embed Culture First (Small Wins)	Maintaining Change	Growth mindset	Supporting the Habits	Method Selection	Goals Regularity and review	Internal & External Resources	Lean 5 Principles (included in process)	Other
Case ID (V001)	X																						
Completed (V002)	X																						
Sample Group (V003)	X																						
Sample Group (other (V004)	X																						
Country (V005)	X																						
Country (other) (V006)	X																						
Work experience (V007)	X							X															
Implemented Lean or TPS (V008)								X															
Implemented Theory of Constraints (V009)								X															
Implemented Agile (Mfg.) (V010)								X															
Implemented Agile (IT) (V011)								X															
Implemented Quality Sytems (V012)								X															
Case Method (V013)	X																						
Combination/ other (V014)																							
Competitive Advantage (V015)																							
Performance Enhanced (V016)				X																			
Staff Morale Incr. (V017)				X								X											
Key Outcomes Comment (V018)				X																			
Role (V019)																							
Role (other) (V020)	X																						
Was Leader (V021)	X																						
Was Leader (Other) (V022)	X																						
Industry (V023)	X																						
Industry (Other) (V024)	X																						
Org. Classification (V025)	X																						
Org. Classification (clarification) (V026)	X																						
Staff No. (V027)	X																						
Impl. Run time (V028)	X																						
Org. Flatness (V029)	X		X											X									
Org. Flatness (other) (V030)	X		X											X									
Journey View (V031)											X					X	X						
Momentum Constant (V032)										X	X					X				X			
Started Well (V033)																							X
Emphasis Proc. Imprv. (V034)					X																X		
Impl. by consultants (V035)																							
Management Commit. (V036)							X																
New Cult. Emphasis (V037)			X			X																	
New Cult Developed (V038)			X			X																	
Staff in Planning. (V039)			X						X														
Sustained Imp. (V040)				X																			
Worker Initiatives (V041)			X											X							X		

	Situational Variables and General Demographic	Planned Change	Emergent Change	Outcomes	Process	Culture	Leadership	Knowledge & Capability	Strategy and Vision	Goals Regularity and review	Journey View	Fostering Behaviours or Resistance	Guiding Coalition	Communication Process	Embed Culture First (Small Wins)	Maintaining Change	Growth mindset	Supporting the Habits	Method Selection	Goals Regularity and review	Internal & External Resources	Lean 5 Principles (included in process)	Other
Used Incentives (V042)												X											
Driven by External Support (V043)																					X		
Developed Self-improving Org. (V044)			X	X		X																	
Financial Situation (V045)																					X		
Financial (Clarification) (V046)																					X		
Mgmt. Planned Well (V047)		X																					
Easy for suggestion/ improvements. (V048)			X											X				X					
Culture Initial priority (V049)			X			X						X			X								
Mgmt. - Effective Com. Process (V050)			X				X							X									
Mgmt. - Vivid Comm. Strategy / Vis] (V051)			X				X		X			X		X									
Mgmt. - Comm. Staff Role (Alignment) (V052)			X				X		X			X		X									
Mgmt. - Vivid Com. Steps of Change (V053)			X				X					X		X									
Mgmt. commit. training (V054)			X				X																X
Mgmt. had exclnt lean knwldge (V055)							X	X															
Staff Trusted Mgmt (V056)			X			X	X					X											
Involved all Staff (V057)			X			X																	
Lean / flow accounting (V058)																							
Flow focus (vs utilisation) (V059)					X														X			X	
Mgmt .Press. was needed (V060)		X																					
Mgmt. Press still Needed (V061)		X	X	X								X											
Staff Capability (V062)								X													X		
Technology Capability (V063)																					X		
Management Capability (V064)							X	X													X		
Consultant Capability (V065)							X	X													X		
Impl. Leader Capability (V066)							X	X													X		
Mgmt understood tools/ methods (V067)							X	X											X				
Mgmt understood as a new culture/ philosophy (V068)			X			X	X	X															
Groups of Positive Staff (V069)													X			X		X					
Easy to maintain momentum (V070)			X			X						X				X							
Fear as a Motivator (V071)							X		X			X				X							
Small wins prominent (V072)															X	X							
Consultants as a coach. (V073)																					X		
New staff identity devel. (V074)			X			X											X						
Growth mindset (can learn/ improve) (V075)																	X						
Staff warned of the struggle (V076)												X					X						
Guiding coalition supporting. (V077)													X			X					X		
Program/ Structure/ Regularity (V078)										X										X			
Individual support in adjusting (V079)							X											X					
Standard work developed (V080)																		X					
Staff meetings. (V081)										X								X		X			
Performance review/ support (V082)										X								X		X			
Impl. review and planning (V083)									X	X										X			

	Situational Variables and General Demographic	Planned Change	Emergent Change	Outcomes	Process	Culture	Leadership	Knowledge & Capability	Strategy and Vision	Goals Regularity and review	Journey View	Fostering Behaviours or Resistance	Guiding Coalition	Communication Process	Embed Culture First (Small Wins)	Maintaining Change	Growth mindset	Supporting the Habits	Method Selection	Goals Regularity and review	Internal & External Resources	Lean 5 Principles (included in process)	Other
PCMH (Previous bad experiences) (V084)												X											
Information Systems (V085)					X														X				
5S System (V086)					X														X				
Just In Time Manufacture (V087)					X														X				
A3 Management, or Nemawashi or Catchball process (V088)					X									X					X				
Total Productive Maintenance (V089)					X														X				
Kaizen (Kaikuku) Improvement Events (V090)															X	X			X				
5 Why's (V091)					X														X				
Simple problem solving. (V092)																			X				
Defining Value (V093)					X																	X	
Pull Systems (V094)					X																	X	
Kanban (V095)					X														X				
Statistical Methods (V096)					X														X				
Mapping Value Stream (V097)					X														X			X	
Visual Systems (V098)					X													X	X				
Root Cause Analysis (V099)					X														X				
Engaging suppliers (V100)					X	X															X		X
Engaging customers (V101)					X	X															X		X
Employees resisted change (V102)												X				X							
Culture similar or conducive already exist.] (V103)			X	X		X																	X
Staff had KPIs/ clear goals (V104)									X	X									X	X			
Mgmt. contin. to learn and participate (V105)							X	X															
Mgmt established lean knowledge at start (V106)							X	X															
Other factors felt important (V107)																							X
Do differently. (V108)																							X
Significant positive outcomes (V109)				X																			
Significant negative outcomes (V110)				X																			
Email (V111)																							X

Figure 340 Experiment Two—questions by overview conceptual framework

14.2 Survey Questions by Variable Name

14.2.1 Questionnaire One

Variable	Full Question
Case ID (V001)	id
Completed (V002)	Completed
Sample Groups (V003)	How did you find this survey?
Sample Group (other) (V004)	How did you find this survey? [Other]
Gender (V005)	Gender
Country (V006)	In what country do you live?
Country (other) (V007)	In what country do you live? [Other]
Diploma (V008)	What training do you have? [Diploma (2 year/1 year)]
Bachelors (V009)	What training do you have? [Bachelor’s Degree]
Post-graduate (V010)	What training do you have? [Post Graduate Degree]
Trade (V011)	What training do you have? [Trade or Advanced Trade Certification]
On Job (V012)	What training do you have? [Industry/On Job Training]
Toyota (V013)	What training do you have? [Toyota Employee]
Six-Sigma Cert. (V014)	What training do you have? [Six-Sigma Certification]
LSS Cert. (V015)	What training do you have? [Lean Six Sigma Certification]
NZTE Course (V016)	What training do you have? [NZTE Lean Seminar (2 day)]
Training - Other (V017)	What training do you have? [Other]
Accounting (V018)	What field was your study? [Accounting]
Business (V019)	What field was your study? [Business]
Engineering (V020)	What field was your study? [Engineering]
IT (V021)	What field was your study? [Information Technology]
Law (V022)	What field was your study? [Law]
Arts (V023)	What field was your study? [Arts]
Medicine (V024)	What field was your study? [Medicine]
Health - Other (V025)	What field was your study? [Health Sciences - Other]
Degree - Other (V026)	What field was your study? [Other]
Industry (V027)	What industry are you in?
Industry - other (V028)	What industry are you in? [Other]
Role (V029)	What best describes your role?
Role - other (V030)	What best describes your role? [Other]
Business Staff (V031)	How many staff (employees) does the business have?(approximate)
Work Experience (V032)	Approximately how many years work experience do you have?
Lean - Familiarity (V033)	To what extent are you familiar with the following? [Lean and/or the TPS (or variation of e.g. ACE, Lean Health etc.)]
TOC - Familiarity (V034)	To what extent are you familiar with the following? [TOC - Theory of Constraints]
Agile Mfg. - Familiarity (V035)	To what extent are you familiar with the following? [Agile Manufacturing]
Agile IT - Familiarity (V036)	To what extent are you familiar with the following? [Agile Software/IT]
Six Sigma - Familiarity (V037)	To what extent are you familiar with the following? [Six sigma]
TPS - Familiarity (V038)	To what extent are you familiar with the following? [Toyota Production System]
Quality Sys - Familiarity (V039)	To what extent are you familiar with the following? [Total Quality Management or Quality Circles/Systems]
Cost Acc. - Familiarity (V040)	To what extent are you familiar with the following? [Cost Accounting]
Reasons not pursued Lean knowledge (V041)	We want to assess the reason people do or do not seek out more knowledge of the systems (particularly Lean). We would appreciate any reasons why you have not obtained further knowledge of Lean. Example: You may believe it is not important for your position to have the advanced knowledge or that Lean is not relevant to your industry or you have no time or are simply unaware of its existence.
Reasons pursued Lean knowledge (V042)	We want to assess the reason people do or do not seek out more knowledge of the systems (particularly Lean). What made you seek out or learn about Lean ? Example: You may believe it is important for your position to have the advanced knowledge or been forced to in your job.
Lean - Impl. (V043)	To what extent have you implemented the following? [Lean and/or the TPS (or variation of e.g. ACE, Lean Health etc.)]
Agile Mfg. - Impl. (V044)	To what extent have you implemented the following? [Agile

	Manufacturing]
Agile IT - Impl. (V045)	To what extent have you implemented the following? [Agile Software/IT]
TOC - Impl. (V046)	To what extent have you implemented the following? [TOC - Theory of Constraints]
Quality Sys - Impl. (V047)	To what extent have you implemented the following? [Total Quality Management/Quality Circles]
Six-Sigma - Impl. (V048)	To what extent have you implemented the following? [Six-Sigma]
Lean SS - Impl. (V049)	To what extent have you implemented the following? [Lean six-sigma]
Repacking of JIT/Qual. Sys (V050)	Do the following statements match your understanding of lean? (answering "don't know" means you don't understand the statement) [Lean is simple repacking of JIT and quality systems, nothing new.]
Tools, processes (V051)	Do the following statements match your understanding of lean? (answering "don't know" means you don't understand the statement) [Lean implementation is of tools and processes for improving productivity.]
Process Eng. (V052)	Do the following statements match your understanding of lean? (answering "don't know" means you don't understand the statement) [Lean is tools or methods primarily for process or industrial engineers.]
Waste Elimin. (V053)	Do the following statements match your understanding of lean? (answering "don't know" means you don't understand the statement) [Lean means eliminating waste.]
Train & Empower (V054)	Do the following statements match your understanding of lean? (answering "don't know" means you don't understand the statement) [Lean gives workers training and empowerment to solve problems.]
Fragile/Unbuffered (V055)	Do the following statements match your understanding of lean? (answering "don't know" means you don't understand the statement) [Lean means fragile (i.e. without buffers).]
New Systems/Ways (V056)	Do the following statements match your understanding of lean? (answering "don't know" means you don't understand the statement) [Lean is implementation of new systems and ways of doing things to improve productivity.]
Respecting People (V057)	Do the following statements match your understanding of lean? (answering "don't know" means you don't understand the statement) [Lean means respecting people.]
Philos. /Strategy (V058)	Do the following statements match your understanding of lean? (answering "don't know" means you don't understand the statement) [The implementation of a company wide philosophy and strategy.]
Needs regularity and focus (V059)	Do the following statements match your understanding of lean? (answering "don't know" means you don't understand the statement) [Lean implementation process needs regularity and focus for sustained success.]
New label - Indus. Eng. (V060)	Do the following statements match your understanding of lean? (answering "don't know" means you don't understand the statement) [Lean is a new label for industrial engineering and the work of industrial engineers.]
Comment (V061)	Room for comments on the above question (skip if none):
Comp. Advantage (V062)	To what extent does Lean provide a competitive advantage?
Comment (V063)	Room for comment on the above question (e.g. Lean is no good for... ...situations):
The extent that a manager understands Lean is critical for success. (V064)	Lean is an organisational change. Do you agree with the following statements? “The extent that a manager understands Lean and Lean implementation is critical for the success of Lean. Understanding what is critical governs their decision-making, ensuring greater chances of success."
In a small organisations management's understanding is top priority for success. (V065)	In a small organisation (say less than 50 staff) the management's understanding of Lean should be the first and top priority to ensure an implementation is handled properly.
Comment - Management Knowledge crucial (V066)	(Space for comment)
Large impact (V067)	Do you agree the following are crucial in the initial stage (year) of Lean implementation? (Check row headings - Strongly agree is leftmost) [Achieving large high

	impact improvement events to show the benefits.]
Best Methods (V068)	Do you agree the following are crucial in the initial stage (year) of Lean implementation?(Check row headings - Strongly agree is leftmost) [Learning the best improvement methods]
Comm. Process (V069)	Do you agree the following are crucial in the initial stage (year) of Lean implementation?(Check row headings - Strongly agree is leftmost) [Develop an effective communication process]
Staff Identity (V070)	Do you agree the following are crucial in the initial stage (year) of Lean implementation?(Check row headings - Strongly agree is leftmost) [Develop an appropriate staff identity (e.g. "all staff are inventors")]
Small and regular (V071)	Do you agree the following are crucial in the initial stage (year) of Lean implementation? (Check row headings - Strongly agree is leftmost) [Achieve small but regular improvements.]
Key Staff Only (V072)	Do you agree the following are crucial in the initial stage (year) of Lean implementation?(Check row headings - Strongly agree is leftmost) [Involve the key staff only (not all).]
Mgmt. Force (V073)	Do you agree the following are crucial in the initial stage (year) of Lean implementation? (Check row headings - Strongly agree is leftmost) [Management to enforce the best practices to freeze changes.]
Technology (V074)	Do you agree the following are crucial in the initial stage (year) of Lean implementation? (Check row headings - Strongly agree is leftmost) [Implement new technology.]
Simple Techniques (V075)	Do you agree the following are crucial in the initial stage (year) of Lean implementation? (Check row headings - Strongly agree is leftmost) [Use the simple techniques.]
Implementation Focus Comments (V076)	Room for comments (if any) on the above question:
Adv. Sys, MRP ERP (V077)	To what extent would the following be relevant to your organisation? Please answer "Don't know" if you don't know the concept. Don't look up the definitions on internet (except for translation) as we also use the question to assess knowledge. [Advanced Technology Systems,

	MRP/ERP]
Alignment (V078)	To what extent would the following be relevant to your organisation? Please answer "Don't know" if you don't know the concept. Don't look up the definitions on internet (except for translation) as we also use the question to assess knowledge. [Staff alignment with strategy.]
5 S System (V079)	To what extent would the following be relevant to your organisation? Please answer "Don't know" if you don't know the concept. Don't look up the definitions on internet (except for translation) as we also use the question to assess knowledge. [5S System]
Just In Time (V080)	To what extent would the following be relevant to your organisation? Please answer "Don't know" if you don't know the concept. Don't look up the definitions on internet (except for translation) as we also use the question to assess knowledge. [Just In Time Manufacture]
A3 Mgmt. or Nemawashi (V081)	To what extent would the following be relevant to your organisation? Please answer "Don't know" if you don't know the concept. Don't look up the definitions on internet (except for translation) as we also use the question to assess knowledge. [A3 Management or Nemawashi communication process]
TPM (V082)	To what extent would the following be relevant to your organisation? Please answer "Don't know" if you don't know the concept. Don't look up the definitions on internet (except for translation) as we also use the question to assess knowledge. [Total Productive Maintenance]
Kaizen Events (V083)	To what extent would the following be relevant to your organisation? Please answer "Don't know" if you don't know the concept. Don't look up the definitions on internet (except for translation) as we also use the question to assess knowledge. [Kaizen (Kaikaku) Improvement Events]
5 Whys (V084)	To what extent would the following be relevant to your organisation? Please answer "Don't know" if you don't know the concept. Don't look up the definitions on internet (except for translation) as we also use the question to assess knowledge. [5 Whys]
Define Value (V085)	To what extent would the following be relevant to your organisation? Please answer "Don't know" if you

	don't know the concept. Don't look up the definitions on internet (except for translation) as we also use the question to assess knowledge. [Defining Value in the customers eyes]
Pull Systems (V086)	To what extent would the following be relevant to your organisation? Please answer "Don't know" if you don't know the concept. Don't look up the definitions on internet (except for translation) as we also use the question to assess knowledge. [Pull Systems]
Kanban (V087)	To what extent would the following be relevant to your organisation? Please answer "Don't know" if you don't know the concept. Don't look up the definitions on internet (except for translation) as we also use the question to assess knowledge. [Kanban]
Cont. Improvement Cult. (V088)	To what extent would the following be relevant to your organisation? Please answer "Don't know" if you don't know the concept. Don't look up the definitions on internet (except for translation) as we also use the question to assess knowledge. [continuous improvement as a way of life]
Dev. Flow (V089)	To what extent would the following be relevant to your organisation? Please answer "Don't know" if you don't know the concept. Don't look up the definitions on internet (except for translation) as we also use the question to assess knowledge. [Developing flow]
VSM (V090)	To what extent would the following be relevant to your organisation? Please answer "Don't know" if you don't know the concept. Don't look up the definitions on internet (except for translation) as we also use the question to assess knowledge. [Value Stream Mapping]
Visual Systems (V091)	To what extent would the following be relevant to your organisation? Please answer "Don't know" if you don't know the concept. Don't look up the definitions on internet (except for translation) as we also use the question to assess knowledge. [Visual Systems]
Become Learning Org. (V092)	To what extent would the following be relevant to your organisation? Please answer "Don't know" if you don't know the concept. Don't look up the definitions on internet (except for translation) as we also use the question to assess knowledge.

	[Becoming a Lean Learning Organisations]
Root Cause Anal. (V093)	To what extent would the following be relevant to your organisation? Please answer "Don't know" if you don't know the concept. Don't look up the definitions on internet (except for translation) as we also use the question to assess knowledge. [Root Cause Analysis]
Lean/Flow Accounting (V094)	To what extent would the following be relevant to your organisation? Please answer "Don't know" if you don't know the concept. Don't look up the definitions on internet (except for translation) as we also use the question to assess knowledge. [Flow/Lean accounting]
Standard Work (V095)	To what extent would the following be relevant to your organisation? Please answer "Don't know" if you don't know the concept. Don't look up the definitions on internet (except for translation) as we also use the question to assess knowledge. [Standard work]
Final Comment (V096)	You have completed the questions. Before you submit do you have any other comments?
Gap (V097)	
Below variables were inferred from other variables i.e. codes manipulated to aid calculations e.g. for Familiarity and Implementation questions "I don't know" was changed to "not at all"	
Lean - Familiarity (V098)	To what extent are you familiar with the following? [Lean and/or the TPS (or variation of e.g. ACE, Lean Health etc.)]
TOC - Familiarity (V099)	To what extent are you familiar with the following? [TOC - Theory of Constraints]
Agile Mfg. - Familiarity (V100)	To what extent are you familiar with the following? [Agile Manufacturing]
Agile IT - Familiarity (V101)	To what extent are you familiar with the following? [Agile Software/IT]
Six Sigma - Familiarity (V102)	To what extent are you familiar with the following? [Six sigma]
TPS - Familiarity (V103)	To what extent are you familiar with the following? [Toyota Production System]
Quality Sys - Familiarity (V104)	To what extent are you familiar with the following? [Total Quality Management or Quality Circles/Systems]
Cost Acc. - Familiarity (V105)	To what extent are you familiar with the following? [Cost Accounting]
Lean - Impl. (V106)	To what extent have you implemented the following? [Lean and/or the TPS (or variation of e.g.

	ACE, Lean Health etc.)]		Quality Sys - Impl. (V110)	To what extent have you implemented the following? [Total Quality Management or Quality Circles/Systems]
Agile Mfg. - Impl. (V107)	To what extent have you implemented the following? [Agile Manufacturing]		Highest Qualification (V111)	"What training do you have?"
Agile IT - Impl. (V108)	To what extent have you implemented the following? [Agile Software/IT]			
TOC - Impl. (V109)	To what extent have you implemented the following? [TOC - Theory of Constraints]			

Figure 341 Experiment One survey questions by variables name

14.2.2 Questionnaire Two

Refer Figure 342 for questionnaire Two questions alongside their variable identifier.

In the web survey there were additions to the questions; “help” texts given to inform the participants. These can be seen in the full survey question forms attached. Examples of the most important are below:

Ref. V013 - *In this section please answer according to one specific implementation you were personally involved in or witnessed. These are our main questions so we would appreciate you complete this page. Your answers to this section will only be recorded if you click "next" at the bottom of the page.*

Ref. V016 - *By performance we mean an improvement better than would have otherwise been expected. A performance unachievable just by merely adding more resources. This includes doing more or better than previously possible (e.g. financial performance, productivity, quality or delivery).*

Ref. V032 - **This question on momentum assesses whether the implementation was stop-start with significant pauses in progress, involving many lulls in activity.*

Ref. V040 - ***By sustained we mean did the practices or behaviours targeted in the implementation continue beyond the initial period.*

Ref. V045 - *This refers to liquidity or cash flow condition. Please comment at the bottom of this page if you feel this had a particular effect on this implementation.*

Ref. V084 - *Bad experiences in the current business or previous employment. Changes handled poorly may cause resistance to future changes.*

Ref. In various places - *If other than Lean was implemented (e.g. Agile) answer above question for that methodology.*

Variables	**Full Question**			
Case ID (V001)	Case ID		Work experience (V007)	How many years work experience do you have?(Approximately)
Completed (V002)	Did participant click “submit survey”		Implemented Lean or TPS (V008)	To what extent have you implemented the following? [Lean or TPS]
Sample Group (V003)	How did you find out about this survey?		Implemented Theory of Constraints (V009)	To what extent have you implemented the following? [Theory of Constraints]
Sample Group (other (V004)	How did you find out about this survey? [Other]		Implemented	To what extent have you
Country (V005)	In what country do you live?			
Country (other) (V006)	In what country do you live? [Other]			

Agile (Mfg.) (V010)	implemented the following? [Agile Manufacturing]
Implemented Agile (IT) (V011)	To what extent have you implemented the following? [Agile for IT Development]
Implemented Quality Systems (V012)	To what extent have you implemented the following? [Total Quality Management/Quality Circles]
Case Method (V013)	Please confirm what methodology you are basing your answers on.
Combination/other (V014)	Please confirm what methodology you are basing your answers on. [Other]
Competitive Advantage (V015)	Has the implementation provided a competitive advantage?
Performance Enhanced (V016)	Has business performance improved?
Staff Morale Incr. (V017)	Has staff (employee) morale increased since implementation?
Key Outcomes Comment (V018)	Room for comments (skip if none).
Role (V019)	What was your role?
Role (other) (V020)	What was your role? [Other]
Was Leader (V021)	To what extent did you lead the implementation?
Was Leader (Other) (V022)	To what extent did you lead the implementation? [Other]
Industry (V023)	What was the industry?
Industry (Other) (V024)	What was the industry? [Other]
Org. Classification (V025)	What best classifies the organisation?
Org. Classification (clarification) (V026)	What best classifies the organisation? [Other]
Staff No. (V027)	Enter the approximate number of staff? (For the implementation site referenced)
Impl. Run time (V028)	Approximately how long has the implementation being running?
Org. Flatness (V029)	Is the company's structure relatively flat? (A flat structure implies there is little to no middle management so top management is in closer contact with the staff and customers.)
Org. Flatness (other) (V030)	Is the company's structure relatively flat? (A flat structure implies there is little to no middle management so top management is in closer contact with the staff and customers.) [Other]
Journey View (V031)	Answer to what extent the implementation... [was viewed as a journey, an ongoing process.]
Momentum	Answer to what extent the

Constant (V032)	implementation... [had constant momentum (did not stop and start)*]
Started Well (V033)	Answer to what extent the implementation... [started well (good, steady and positive start)]
Emphasis Proc. Imprv. (V034)	Answer to what extent the implementation... [emphasised process improvement, methods or tools]
Impl. by consultants (V035)	Answer to what extent the implementation... [was conducted by consultants]
Management Commit. (V036)	Answer to what extent the implementation... [was committed to by management]
New Cult. Emphasis (V037)	Answer to what extent the implementation... [emphasised a new culture]
New Cult Developed (V038)	Answer to what extent the implementation... [actually developed a new culture]
Staff in Planning. (V039)	Answer to what extent the implementation... [involved and was communicated to the staff in the planning stage]
Sustained Imp. (V040)	Answer to what extent the implementation... [has been sustained**]
Worker Initiatives (V041)	Answer to what extent the implementation... [encourages, facilitates, and involves worker improvement initiatives]
Used Incentives (V042)	Answer to what extent the implementation... [used incentives to motivate staff]
Driven by External Support (V043)	Answer to what extent the implementation... [was initiated because of external support (e.g. government funded consultants or courses)]
Developed Self-improving Org. (V044)	Answer to what extent the implementation... [developed a self-improving organisation]
Financial Situation (V045)	How was the company's finances (liquidity) during implementation?
Financial (Clarification) (V046)	How was the company's finances (liquidity) during implementation? [Other]
Mgmt. Planned Well (V047)	How much do you agree that management...? [planned well for the implementation]
Easy for suggestion/improvements (V048)	How much do you agree that management...? [made it easy for staff to suggest and accomplish improvements]
Culture Initial priority (V049)	How much do you agree that management...? [viewed culture development more important than initial improvement gains]
Mgmt. -	How much do you agree that

Effective Comm. Process (V050)	management...? [used an effective communication process]
Mgmt. - Vivid Comm. Strategy/Vis] (V051)	How much do you agree that management...? [clearly and vividly communicated to staff the company strategy/vision]
Mgmt. - Comm. Staff Role (Alignment) (V052)	How much do you agree that management...? [clearly and vividly communicated how staff roles and initiatives aligned with strategy]
Mgmt. - Vivid Comm. Steps of Change (V053)	How much do you agree that management...? [communicated the specific steps of change clearly]
Mgmt. commit. training (V054)	How much do you agree that management...? [committed to training]
Mgmt. had exclnt lean knwldge (V055)	How much do you agree that management...? [had excellent knowledge of lean]
Staff Trusted Mgmt (V056)	How much do you agree that management...? [had the trust of staff]
Involved all Staff (V057)	How much do you agree that management...? [involved all staff]
Lean/flow accounting (V058)	How much do you agree that management...? [used lean/flow accounting (i.e. non-traditional)]
Flow focus (vs utilisation) (V059)	How much do you agree that management...? [focused on improving flow rather than utilization of people and equipment]
Mgmt. Press. was needed (V060)	How much do you agree that management...? [pressure was needed to enforce the desired behaviour changes.]
Mgmt. Press still Needed (V061)	How much do you agree that management...? [pressure is still needed for staff to maintain the lean behaviours.]
Staff Capability (V062)	What is your estimation of the competence, capability, and calibre of the company's... [Staff]
Technology Capability (V063)	What is your estimation of the competence, capability, and calibre of the company's... [Technology]
Management Capability (V064)	What is your estimation of the competence, capability, and calibre of the company's... [Management]
Consultant Capability (V065)	What is your estimation of the competence, capability, and calibre of the company's... [Consultant]
Impl. Leader Capability (V066)	What is your estimation of the competence, capability, and calibre of the company's... [Implementation leader]
Mgmt. understood tools/methods	Answer to what extent. [Management understood the tools and methods for improvement.]

(V067)	
Mgmt. understood as a new culture/philosophy (V068)	Answer to what extent. [Management understood implementation as a new culture/philosophy.]
Groups of Positive Staff (V069)	Answer to what extent. [Positive staff were grouped together (on purpose or by accident).]
Easy to maintain momentum (V070)	Answer to what extent. [It was easy to maintain momentum for change.]
Fear as a Motivator (V071)	Answer to what extent. [Fear was used as a motivator (e.g. loss of jobs or income).]
Small wins prominent (V072)	Answer to what extent. [Small wins (small events or improvements) were prominent in implementation.]
Consultants as a coach (V073)	Answer to what extent. [Consultants were used as a coach to train others (rather than doing themselves).]
New staff identity devel. (V074)	Answer to what extent. [A new staff identity was developed (e.g. all staff are "Inventors" or "Improvement Engineers").]
Growth mindset (can learn/improve) (V075)	Answer to what extent. [Staff were helped to see that they could learn or improve with effort.]
Staff warned of the struggle (V076)	Answer to what extent. [Staff were warned of the struggle of change and the possibility of momentary failures.]
Guiding coalition supporting (V077)	Answer to what extent. [A guiding coalition or group of key staff were supporting the implementation.]
Program/Structure/Regularity (V078)	Answer to what extent. [A program, structure or regularity for implementation was in place.]
Individual support in adjusting (V079)	Answer to what `extent. [Staff received individual support in adjusting to the change.]
Standard work developed (V080)	Answer to what extent. [Procedures (standard work) were developed.]
Staff meetings(V081)	Give the closest answer. [Staff meetings were held]
Performance review/support (V082)	Give the closest answer. [Performance review or support was provided to individuals]
Impl. review and planning (V083)	Give the closest answer. [Implementation review and planning was done by management]
PCMH (Previous bad experiences) (V084)	Did the staff have previous bad experiences that may have left a negative feeling towards change?
Information	How much where the following a

Systems (V085)	feature of the implementation? [Advanced Information Systems (MRP, ERP, other)]
5S System (V086)	How much where the following a feature of the implementation? [5S System]
Just In Time Manufacture (V087)	How much where the following a feature of the implementation? [Just In Time Manufacture]
A3 Management, or Nemawashi or Catchball process (V088)	How much where the following a feature of the implementation? [A3 Management, or Nemawashi or Catchball process]
Total Productive Maintenance (V089)	How much where the following a feature of the implementation? [Total Productive Maintenance]
Kaizen (Kaikaku) Improvement Events (V090)	How much where the following a feature of the implementation? [Kaizen (Kaikaku) Improvement Events]
5 Whys (V091)	How much where the following a feature of the implementation? [5 Whys]
Simple problem solving(V092)	How much where the following a feature of the implementation? [Used and trained staff in simple problem solving.]
Defining Value (V093)	How much where the following a feature of the implementation? [Defining Value]
Pull Systems (V094)	How much where the following a feature of the implementation? [Pull Systems]
Kanban (V095)	How much where the following a feature of the implementation? [Kanban]
Statistical Methods (V096)	How much where the following a feature of the implementation? [Used statistical methods]
Mapping Value Stream (V097)	How much where the following a feature of the implementation? [Mapping of the value stream]
Visual Systems (V098)	How much where the following a feature of the implementation? [Visual Systems]
Root Cause Analysis (V099)	How much where the following a feature of the implementation? [Root Cause Analysis]
Engaging suppliers (V100)	How much where the following a feature of the implementation? [Engaging suppliers]
Engaging customers (V101)	How much where the following a feature of the implementation? [Engaging customers]
Employees resisted change (V102)	Rate the following. [Did employees resist the change.]
Culture similar or conducive	Rate the following. [Did a culture similar or conducive to the desired

already exist.] (V103)	culture already exist.]
Staff had KPIs/clear goals (V104)	Rate the following. [Were staff given clear goals or performance indicators.]
Mgmt. contin. to learn and participate (V105)	Rate the following. [Did management continue to learn and participate throughout implementation.]
Mgmt. established lean knowledge at start (V106)	Rate the following. [At the start of the implementation did management establish (or have) a sound knowledge of Lean.]
Other factors felt important (V107)	List other factors (if any) that you felt were important to the success and sustainability of the implementation.(e.g. relationship building with customers and suppliers, departmental or other factors)
Do differently. (V108)	What would you do differently?
Significant positive outcomes (V109)	What were significant positive outcomes for the organisation?
Significant negative outcomes (V110)	Were there significant negative outcomes? (List if any)
Email (V111)	Are you happy to be contacted regarding your answers to this survey? If so leave your email address here. Your answers will no longer be anonymous to the researchers but will not be shared with other parties.
Completed survey #1 (V112)	We had a previous survey entitled "Knowledge Survey (Productivity Systems)". Some of these questions are listed below. Have you previously completed them?
The extent that a manager understands Lean is critical for success. (V113)	Lean is an organisational change. Do you agree with the following statements? “The extent that a manager understands Lean and Lean implementation is critical for the success of Lean. Understanding what is critical governs their decision-making, ensuring greater chances of success."
In a small organisations management's understanding is top priority for success. (V114)	In a small organisation (say less than 50 staff) the management's understanding of Lean should be the first and top priority to ensure an implementation is handled properly.
Fam. Lean or TPS (V115)	To what extent are you familiar with the following? [Lean or TPS]
Fam. Theory of	To what extent are you familiar with

Constraints (V116)	the following? [Theory of Constraints]
Fam. Agile Manufacturing (V117)	To what extent are you familiar with the following? [Agile Manufacturing]
Fam. Agile for IT (V118)	To what extent are you familiar with the following? [Agile for IT Development]
Fam. Quality Systems (V119)	To what extent are you familiar with the following? [Total Quality Management/Quality Circles]
Repacking (V120)	Do the following statements represent your understanding of Lean? (Answer "not at all" if the statement does not represent your understanding or "don't know" if you don't know about that concept) [Lean is a simple repacking of JIT and quality systems, nothing new.]
Tools, processes (V121)	Do the following statements represent your understanding of Lean? (Answer "not at all" if the statement does not represent your understanding or "don't know" if you don't know about that concept) [Lean implementation is of tools and processes for improving productivity.]
Process Eng. (V122)	Do the following statements represent your understanding of Lean? (Answer "not at all" if the statement does not represent your understanding or "don't know" if you don't know about that concept) [Lean is tools or methods primarily for process or industrial engineers.]
Waste Elimin. (V123)	Do the following statements represent your understanding of Lean? (Answer "not at all" if the statement does not represent your understanding or "don't know" if you don't know about that concept) [Lean means eliminating waste.]
Train & Empower (V124)	Do the following statements represent your understanding of Lean? (Answer "not at all" if the statement does not represent your understanding or "don't know" if you don't know about that concept) [Lean gives workers training and empowerment to solve problems.]
Fragile/Unbuffered (V125)	Do the following statements represent your understanding of Lean? (Answer "not at all" if the statement does not represent your understanding or "don't know" if you don't know about that concept) [Lean means fragile (i.e. without buffers).]
New Systems/Ways (V126)	Do the following statements represent your understanding of Lean? (Answer "not at all" if the statement does not
	represent your understanding or "don't know" if you don't know about that concept) [Lean is the implementation of new systems and ways of doing things to improve productivity.]
Respecting People (V127)	Do the following statements represent your understanding of Lean? (Answer "not at all" if the statement does not represent your understanding or "don't know" if you don't know about that concept) [Lean means respecting people.]
Philos./Strategy (V128)	Do the following statements represent your understanding of Lean? (Answer "not at all" if the statement does not represent your understanding or "don't know" if you don't know about that concept) [Lean is the implementation of a company wide philosophy and strategy.]
Needs regularity and focus (V129)	Do the following statements represent your understanding of Lean? (Answer "not at all" if the statement does not represent your understanding or "don't know" if you don't know about that concept) [Lean implementation needs regularity and focus for sustained success.]
New label - Indus. Eng. (V130)	Do the following statements represent your understanding of Lean? (Answer "not at all" if the statement does not represent your understanding or "don't know" if you don't know about that concept) [Lean is a new label for industrial engineering and the work of industrial engineers.]
Caused you to learn about Lean (V131)	What caused you to learn about Lean?
Final Comment (V132)	You have completed the questions. Before you submit, do you have any other comments?
Below Variables were added by inference, calculation, and coding from text responses.	
Consultant Use (V133)	Implied No Consultant (Based on V035/065/073)
Internal Lean capability (ex V107) (V134)	Internal Lean capability (e.g. advisors, champion or training) (comment ex V107)
Team Focus (ex V107) (V135)	Team Focus (working together breaking down barriers)(comment ex V107)
Lean as Cost Cutting (ex V018) (V136)	Lean as Cost Cutting e.g. Layoff affect morale (V018)
Lay off or staff loss (ex V018 or v110) (V137)	Lay off or staff loss (comment ex V018 or v110)
Remove -ve	Remove -ve influence/incompatible

influence (ex V018 or v110) (V138)	persons (comment ex V018 or v110)
Lay off, other (ex V018 or v110) (V139)	Employee lay off, other (comment ex V018 or v110)
V018, or v110 had comments	V018, or v110 had comments

(V140)	
Invalid (V141)	Invalid, remove from analysis
Reason removed (V142)	
Data_set (V143)	Randomised selection for train and testing data set
Completeness (V144)	Implementation Answer Completeness

Figure 342 Experiment Two survey questions by variables name.

14.3 Printed Versions of the Web Questionnaires

14.3.1 Questionnaire One, Knowledge Survey

See the following pages.

Knowledge Survey (Productivity Systems)

Please participate.
We need your responses.

Our purpose is to survey the knowledge of our subject amongst survey participants. If you think you have no knowledge or experience in this field we still need to hear from you as much as those who do.

A summary of findings can be sent to those who request.

By commencing the survey you give consent for your responses to be used as part of this research study and that you are satisfied with the measures that will be taken to protect your identity and interests. Further information on the research and participation can be found by clicking here.

Click "next" to begin the survey. We prefer you complete all questions but you may skip questions and submit on the last page if you become short on time.

There are 24 questions in this survey

Questions

In all questions we aim to assess what is known by participants prior to the survey. Please do not look up definitions or answers (except for translation).

1 How did you find this survey?

Please choose **only one** of the following:

- ○ LinkedIn Manufacturing Group
- ○ LinkedIn Small Business Group
- ○ LinkedIn Business Group
- ○ LinkedIn Doctorate Group
- ○ Facebook
- ○ NZ MSI Discussion Group (e.g. LinkedIn)
- ○ Personal referral from Antony Pearce (e.g. email)
- ○ Other ______

2

Please choose **only one** of the following:

- ○ Female
- ○ Male

3 In what country do you live?

Please choose **only one** of the following:

- ○ United Kingdom
- ○ New Zealand
- ○ United States of America
- ○ Canada
- ○ Australia
- ○ Other ______

4 What training do you have?

Please choose **all** that apply:

- ☐ Diploma (2 year/ 1 year)
- ☐ Bachelor's Degree
- ☐ Post Graduate Degree
- ☐ Trade or Advanced Trade Certification
- ☐ Industry/ On Job Training
- ☐ Toyota Employee
- ☐ Six-Sigma Certification
- ☐ Lean Six Sigma Certification
- ☐ NZTE Lean Seminar (2 day)
- ☐ Other relevant: ______

5 What field was your study?

Only answer this question if the following conditions are met:
°

-------- Scenario 1 --------

Answer was at question '4 [Training]' (What training do you have?)

-------- or Scenario 2 --------

Answer was at question '4 [Training]' (What training do you have?)

-------- or Scenario 3 --------

Answer was at question '4 [Training]' (What training do you have?)

Please choose **all** that apply:

- [ ] Accounting
- [ ] Business
- [ ] Engineering
- [ ] Information Technology
- [ ] Law

- [ ] Arts
- [ ] Medicine
- [ ] Health Sciences - Other
- [ ] Other: ____

6 What industry are you in?

Please choose **only one** of the following:

- ○ Manufacturing
- ○ IT Development
- ○ Construction Industry
- ○ Engineering (Other)
- ○ Design/ Innovation (non engineering)
- ○ Health Services
- ○ Public Service (other)
- ○ Logistics/ Transport
- ○ Service Organisation Other
- ○ Education
- ○ Retail
- ○ Legal
- ○ Science
- ○ I am a student
- ○ Other ____

7 What best describes your role?

Only answer this question if the following conditions are met:
° Answer was NOT 'I am a student' at question '6 [Industry]' (What industry are you in?)

Please choose **only one** of the following:

- ○ Owner Operator
- ○ Middle Management
- ○ Senior Management
- ○ Business Consultant/ Advisor

- ○ Engineering administration, planning and/ or procurement
- ○ Technical role
- ○ General Staff/ Worker
- ○ Other ____

8 How many staff does the business have? (approximate)

Only answer this question if the following conditions are met:
° Answer was NOT 'I am a student' at question '6 [Industry]' (What industry are you in?)

Please write your answer here:

____

9 Approximately how many years work experience do you have?

Please choose **only one** of the following:

- ○ 0 years
- ○ 0 to 1 year
- ○ 1 to 3 years
- ○ 3 to 5 years
- ○ 5 to 10 years
- ○ 10 to 15 years
- ○ 15 to 25 years
- ○ 25 plus years

10 To what extent are you familiar with the following?
Please choose the appropriate response for each item:

	Not at all	Small extent	Moderate extent	Great extent	Very great extent	I don't know this.
Lean and/or the TPS (or variation of e.g. ACE, Lean Health etc.)	○	○	○	○	○	○
TOC - Theory of Constraints	○	○	○	○	○	○
Agile Manufacturing	○	○	○	○	○	○
Agile Software/ IT	○	○	○	○	○	○
Six sigma	○	○	○	○	○	○
Toyota Production System	○	○	○	○	○	○
Total Quality Management or Quality Circles/ Systems	○	○	○	○	○	○
Cost Accounting	○	○	○	○	○	○

11 We want to assess the reason people do or do not seek out more knowledge of the systems (particularly Lean). We would appreciate any reasons why you have not obtained further knowledge of Lean.
Example: You may believe it is not important for your position to have the advanced knowledge or that Lean is not relevant to your industry or you have no time or are simply unaware of its existence.

Only answer this question if the following conditions are met:
° Answer was 'Moderate extent' or 'Small extent' or 'Not at all' at question '10 [Concepts]' (To what extent are you familiar with the following? (Lean and/or the TPS (or variation of e.g. ACE, Lean Health etc.)))

Please write your answer here:

12 We want to assess the reason people do or do not seek out more knowledge of the systems (particularly Lean). What made you seek out or learn about Lean ?
Example: You may believe it is important for your position to have the advanced knowledge or been forced to in your job.

Only answer this question if the following conditions are met:
° Answer was 'Very great extent' or 'Great extent' at question '10 [Concepts]' (To what extent are you familiar with the following? (Lean and/or the TPS (or variation of e.g. ACE, Lean Health etc.))

Please write your answer here:

13 To what extent have you implemented the following?
Please choose the appropriate response for each item:

	Not at all	Small extent	Moderate extent	Great extent	Very great extent	I don't know this.
Lean and/or the TPS (or variation of e.g. ACE, Lean Health etc.)	○	○	○	○	○	○
Agile Manufacturing	○	○	○	○	○	○
Agile Software/ IT	○	○	○	○	○	○
TOC - Theory of Constraints	○	○	○	○	○	○
Total Quality Management/ Quality Circles	○	○	○	○	○	○
Six-Sigma	○	○	○	○	○	○
Lean six-sigma	○	○	○	○	○	○

14 Do the following statements match your understanding of lean?
(answering "don't know" means you don't understand the statement)

Only answer this question if the following conditions are met:
° Answer was 'Moderate extent' or 'Small extent' or 'Great extent' or 'Very great extent' at question '10 [Concepts]' (To what extent are you familiar with the following? (Lean and/or the TPS (or variation of e.g. ACE, Lean Health etc.))
Please choose the appropriate response for each item:

	Not at all	Small extent	Moderate extent	Great extent	Very great extent	I don't know this.
Lean is simple repacking of JIT and quality systems, nothing new.	○	○	○	○	○	○
Lean implementation is of tools and processes for improving productivity.	○	○	○	○	○	○
Lean is tools or methods primarily for process or industrial engineers.	○	○	○	○	○	○

	Not at all	Small extent	Moderate extent	Great extent	Very great extent	I don't know this.
Lean means eliminating waste.	○	○	○	○	○	○
Lean gives workers training and empowerment to solve problems.	○	○	○	○	○	○
Lean means fragile (i.e. without buffers).	○	○	○	○	○	○
Lean is implementation of new systems and ways of doing things to improve productivity.	○	○	○	○	○	○
Lean means respecting people.	○	○	○	○	○	○
The implementation of a company wide philosophy and strategy.	○	○	○	○	○	○
Lean implementation process needs regularity and focus for sustained success.	○	○	○	○	○	○
Lean is a new label for industrial engineering and the work of industrial engineers.	○	○	○	○	○	○

15 Room for comments on the above question (skip if none):

Only answer this question if the following conditions are met:
° Answer was 'Very great extent' or 'Great extent' or 'Moderate extent' or 'Small extent' at question '10 [Concepts]' (To what extent are you familiar with the following? (Lean and/or the TPS (or variation of e.g. ACE, Lean Health etc.)))

Please write your answer here:

16 To what extent does Lean provide a competitive advantage?

Only answer this question if the following conditions are met:
° Answer was 'Small extent' or 'Moderate extent' or 'Great extent' or 'Very great extent' at question '10 [Concepts]' (To what extent are you familiar with the following? (Lean and/or the TPS (or variation of e.g. ACE, Lean Health etc.)))

Please choose **only one** of the following:

- ○ Not at all
- ○ Small extent
- ○ Moderate extent
- ○ Great extent
- ○ Very great extent
- ○ I don't know this.

17 Room for comment on the above question (e.g. Lean is no good for... ...situations):

Only answer this question if the following conditions are met:
° Answer was 'Small extent' or 'Moderate extent' or 'Great extent' or 'Very great extent' at question '10 [Concepts]' (To what extent are you familiar with the following? (Lean and/or the TPS (or variation of e.g. ACE, Lean Health etc.)))

Please write your answer here:

Questions set 2 / 2

These are the final questions. We appreciate your time thus far. If you are out of time you are able to skip questions and submit. But we do appreciate all the answers we can get.

18 Lean is an organisational change. Do you agree with the following statements?

"The extent that a manager understands Lean and Lean implementation is critical for the success of Lean. Understanding what is critical governs their decision-making, ensuring greater chances of success."

Please choose only one of the following:

- ○ **Strongly agree**
- ○ **Somewhat agree**
- ○ **Neutral**
- ○ **Somewhat disagree**
- ○ **Strongly disagree**
- ○ **Don't know**

19 In a small organisation (say less than 50 staff) the management's understanding of Lean should be the first and top priority to ensure an implementation is handled properly.

Please choose only one of the following:

- ○ **Strongly agree**
- ○ **Somewhat agree**
- ○ **Neutral**
- ○ **Somewhat disagree**
- ○ **Strongly disagree**
- ○ **Don't know**

20

Please write your answer here:

LimeSurvey - Knowledge Survey (Productivity Systems) http://tiro.co.nz/survey/admin/admin.php?action=showprintablesurvey...

21 Do you agree the following are crucial in the initial stage (year) of Lean implementation?
(Check row headings - Strongly agree is leftmost)

Please choose the appropriate response for each item:

	Strongly agree	Somewhat agree	Neutral	Somewhat disagree	Strongly disagree	Don't know
Achieving large high impact improvement events to show the benefits.	○	○	○	○	○	○
Learning the best improvement methods	○	○	○	○	○	○
Develop an effective communication process	○	○	○	○	○	○
Develop an appropriate staff identity (e.g. "all staff are inventors")	○	○	○	○	○	○
Achieve small but regular improvements.	○	○	○	○	○	○
Involve the key staff only (not all).	○	○	○	○	○	○
Management to enforce the best practices to freeze changes.	○	○	○	○	○	○
Implement new technology.	○	○	○	○	○	○
Use the simple techniques.	○	○	○	○	○	○

22 Room for comments (if any) on the above question:

Please write your answer here:

23 To what extent would the following be relevant to your organisation?
Please answer "Don't know" if you don't know the concept. Don't look up the

definitions on internet (except for translation) as we also use the question to assess knowledge.

Please choose the appropriate response for each item:

	Not at all	Small extent	Moderate extent	Great extent	Very great extent	I don't know this.
Advanced Technology Systems, MRP/ ERP	○	○	○	○	○	○
Staff alignment with strategy.	○	○	○	○	○	○
5S System	○	○	○	○	○	○
Just In Time Manufacture	○	○	○	○	○	○
A3 Management or Nemawashi communication process	○	○	○	○	○	○
Total Productive Maintenance	○	○	○	○	○	○
Kaizen (Kaikaku) Improvement Events	○	○	○	○	○	○
5 Why's	○	○	○	○	○	○
Defining Value in the customers eyes	○	○	○	○	○	○
Pull Systems	○	○	○	○	○	○
Kanban	○	○	○	○	○	○
continuous improvement as a way of life	○	○	○	○	○	○
Developing flow	○	○	○	○	○	○
Value Stream Mapping	○	○	○	○	○	○
Visual Systems	○	○	○	○	○	○
Becoming a Lean Learning Organisation	○	○	○	○	○	○
Root Cause Analysis	○	○	○	○	○	○
Flow /Lean accounting	○	○	○	○	○	○
Standard work	○	○	○	○	○	○

Comment

24 You have completed the questions. Before you submit do you have any other comments?

Please write your answer here:

Thank you!

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Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

Thank you for your participation in this survey. Please pass on the following to others for their participation.

A survey you may be interested in: http://bit.ly/ProductivityKnowledge

If you have any questions about the research and its finding you may send emails to: Mr. Antony Pearce - antony.pearce@pg.canterbury.ac.nz - or Dr. Dirk Pons - dirk.pos@canterbury.ac.nz -

Submit your survey.
Thank you for completing this survey.

14.3.2 Questionnaire Two, Implementation Experiment

See the following pages.

Lean Implementation (and Similar)

Please participate.
We need your responses.

UNIVERSITY OF CANTERBURY
Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

Our purpose is to survey the experiences of those who have been involved in Lean implementations or similar (e.g. Agile and TPS).

We appreciate your completion of all the questions but you may skip questions and submit on the last page if you run out of time.

By commencing the survey you give consent for your responses to be used as part of this research study and that you are satisfied with the measures that will be taken to protect your identity and interests. Further information on the research and participation can be found by clicking here.

Click "next" to begin the survey.

There are 37 questions in this survey

Basic Demographics

1 How did you find out about this survey?

Please choose **only one** of the following:

- Lean Six-sigma Group Discussion (LinkedIn)
- Lean Group Discussion (LinkedIn)
- Direct Contact (e.g. email message)
- NZTE Contact (e.g. Email)
- Other

2 In what country do you live?

Please choose **only one** of the following:

- United Kingdom
- New Zealand
- United States of America
- Canada

- Australia
- Other

3 How many years work experience do you have? (Approximately)

Please choose **only one** of the following:

- 0 years
- 0 to 1 year
- 1 to 3 years
- 3 to 5 years
- 5 to 10 years
- 10 to 15 years
- 15 to 25 years
- 25 plus years

4 To what extent have you implemented the following?

Please choose the appropriate response for each item:

	Not at all	Small extent	Moderate extent	Great extent	Very great extent	I don't know this.
Lean or TPS	○	○	○	○	○	○
Theory of Constraints	○	○	○	○	○	○
Agile Manufacturing	○	○	○	○	○	○
Agile for IT Development	○	○	○	○	○	○
Total Quality Management/ Quality Circles	○	○	○	○	○	○

Implementation Questions

In this section please answer according to one specific implementation you were personally involved in or witnessed. These are our main questions so we would appreciate you complete this page. Your answers to this section will only be recorded if you click "next" at the bottom of the page.

5 Please confirm what methodology you are basing your answers on.

Please choose **only one** of the following:

- ○ Lean
- ○ Lean Six-sigma
- ○ Agile for IT Industry
- ○ Other

6 Has the implementation provided a competitive advantage?

Please choose **only one** of the following:

- ○ Not at all
- ○ Small extent
- ○ Moderate extent
- ○ Great extent
- ○ Very great extent
- ○ I don't know this.

7 Has business performance improved?

Please choose **only one** of the following:

- ○ Not at all
- ○ Small extent
- ○ Moderate extent
- ○ Great extent
- ○ Very great extent
- ○ I don't know this.

By performance we mean an improvement better than would have otherwise been expected. A performance unachievable just by merely adding more resources. This includes doing more or better than previously possible (e.g. financial performance, productivity, quality or delivery).

8 Has staff morale increased since implementation?

Please choose **only one** of the following:

LimeSurvey - Lean Implementation (and Similar)

- ○ Not at all
- ○ Small extent
- ○ Moderate extent
- ○ Great extent
- ○ Very great extent
- ○ I don't know this.

9 Room for comments (skip if none).

Please write your answer here:

10 What was your role?

Please choose **only one** of the following:

- ○ Owner Operator
- ○ Middle Management
- ○ Senior Management
- ○ Business Consultant / Advisor
- ○ Engineering administration, planning and / or procurement
- ○ Technical role
- ○ General Staff / Worker
- ○ Other

11 To what extent did you lead the implementation?

Please choose **only one** of the following:

- ○ Not at all
- ○ Small extent
- ○ Moderate extent
- ○ Great extent
- ○ Very great extent

- ◯ I don't know this.
- ◯ Other [ ]

12 What was the industry?

Please choose **only one** of the following:

- ◯ Manufacturing
- ◯ IT Development
- ◯ Construction Industry
- ◯ Engineering (Other)
- ◯ Design / Innovation (non engineering)
- ◯ Health Services
- ◯ Public Service (other)
- ◯ Logistics/ Transport
- ◯ Service Organisation Other
- ◯ Education
- ◯ Retail
- ◯ Other [ ]

13 What best classifies the organisation?

Please choose **only one** of the following:

- ◯ High Production Volume, Low Product Variations
- ◯ Low Production Volume, High Product Variations
- ◯ Medium Production Volume, Medium Product Variations
- ◯ Service Organisation
- ◯ Design or Design Build (Engineering Design, Graphic Design, Software Development etc.)
- ◯ Other [ ]

14 Enter the approximate number of staff? *(For the implementation site referenced)*

Please write your answer here:

[ ]

15 Approximately how long has the implementation being running?

Please choose **only one** of the following:

- ◯ 0 to 1 year

- ◯ 1 to 2 years
- ◯ 2 to 3 years
- ◯ 3 to 5 years
- ◯ 5 to 10 years
- ◯ 10 to 15 years
- ◯ 15 years or more

If you are not sure of current state of implementation please just list the years you observed it.

16 Is the company's structure relatively flat?
(A flat structure implies there is little to no middle management so top management is in closer contact with the staff and customers.)

Please choose **only one** of the following:

- ◯ Not at all
- ◯ Small extent
- ◯ Moderate extent
- ◯ Great extent
- ◯ Very great extent
- ◯ I don't know this.
- ◯ Other [ ]

17 Answer to what extent the implementation...
Please choose the appropriate response for each item:

	Not at all	Small extent	Moderate extent	Great extent	Very great extent	I don't know this.
was viewed as a journey, an ongoing process.	◯	◯	◯	◯	◯	◯
had constant momentum (did not stop and start)*	◯	◯	◯	◯	◯	◯
started well (good, steady and positive start)	◯	◯	◯	◯	◯	◯
emphasised process improvement, methods or tools	◯	◯	◯	◯	◯	◯
was conducted by consultants	◯	◯	◯	◯	◯	◯
was committed to by management	◯	◯	◯	◯	◯	◯
emphasised a new culture	◯	◯	◯	◯	◯	◯

	Not at all	Small extent	Moderate extent	Great extent	Very great extent	I don't know this.
actually developed a new culture	○	○	○	○	○	○
involved and was communicated to the staff in the planning stage	○	○	○	○	○	○
has been sustained**	○	○	○	○	○	○
encourages, facilitates, and involves worker improvement initiatives	○	○	○	○	○	○
used incentives to motivate staff	○	○	○	○	○	○
was initiated because of external support (e.g. government funded consultants or courses)	○	○	○	○	○	○
developed a self-improving organisation	○	○	○	○	○	○

*This question on momentum assesses whether the implementation was stop-start with significant pauses in progress, involving many lulls in activity.
**By sustained we mean did the practices or behaviours targeted in the implementation continue beyond the initial period.

18 How was the company's finances (liquidity) during implementation?

Please choose **only one** of the following:

- ○ Bad
- ○ Poor
- ○ Adequate
- ○ Good
- ○ Excellent
- ○ Don't know or Not applicable
- ○ Other

This refers to liquidity or cash flow condition. Please comment at the bottom of this page if you feel this had a particular effect on this implementation.

19 How much do you agree that management...

Please choose the appropriate response for each item:

	Not at all	Small extent	Moderate extent	Great extent	Very great extent	I don't know this.
planned well for the implementation	○	○	○	○	○	○

	Not at all	Small extent	Moderate extent	Great extent	Very great extent	I don't know this.
made it easy for staff to suggest and accomplish improvements	○	○	○	○	○	○
viewed culture development more important than initial improvement gains	○	○	○	○	○	○
used an effective communication process	○	○	○	○	○	○
clearly and vividly communicated to staff the company strategy / vision	○	○	○	○	○	○
clearly and vividly communicated how staff roles and initiatives aligned with strategy	○	○	○	○	○	○
communicated the specific steps of change clearly	○	○	○	○	○	○
committed to	○	○	○	○	○	○
training had	○	○	○	○	○	○
excellent knowledge of lean						○
had the trust of staff	○	○	○	○	○	
involved all staff	○	○	○	○	○	○
used lean / flow accounting (i.e. non traditional)	○	○	○	○	○	○
focused on improving flow rather than utilization of people and equipment	○	○	○	○	○	○
pressure was needed to enforce the desired behaviour changes.	○	○	○	○	○	○
pressure is still needed for staff to maintain the lean behaviours.	○	○	○	○	○	○

If "other" than Lean was implemented (e.g. Agile) answer for that methodology in the above question set.

20 What is your estimation of the competence, capability, and calibre of the company's...

Please choose the appropriate response for each item:

	Masterful	Capable	Basic ability	Limited ability	None/Not at all	Don't know or Not applicable
Staff	○	○	○	○	○	○
Technology	○	○	○	○	○	○

	Masterful	Capable	Basic ability	Limited ability	None/Not at all	Don't know or Not applicable
Management						
Consultant						
Implementation leader						

21 Answer to what extent.
Please choose the appropriate response for each item:

	Not at all	Small extent	Moderate extent	Great extent	Very great extent	I don't know this.
Management understood the tools and methods for improvement.						
Management understood implementation as a new culture/ philosophy.						
Positive staff were grouped together (on purpose or by accident).						
It was easy to maintain momentum for change.						
Fear was used as a motivator (e.g. loss of jobs or income).						
Small wins (small events or improvements) were prominent in implementation.						
Consultants were used as a coach to train others (rather than doing themselves).						
A new staff identity was developed (e.g. all staff are "Inventors" or "Improvement Engineers").						
Staff were helped to see that they could learn or improve with effort.						
Staff were warned of the struggle of change and the possibility of momentary failures.						
A guiding coalition or group of key staff were supporting the						

LimeSurvey - Lean Implementation (and Similar)

	Not at all	Small extent	Moderate extent	Great extent	Very great extent	I don't know this.
implementation.						
A program, structure or regularity for implementation was in place.						
Staff received individual support in adjusting to the change.						
Procedures (standard work) were developed.						

22 Give the closest answer.
Please choose the appropriate response for each item:

	Daily	Weekly	Monthly	Quarterly	Bi-annually	Annually	Don't Know
Staff meetings were held							
Performance review or support was provided to individuals							
Implementation review and planning was done by management							

23 Did the staff have previous bad experiences that may have left a negative feeling towards change?

Please choose **only one** of the following:

- Not at all
- Small extent
- Moderate extent
- Great extent
- Very great extent
- I don't know this.

Bad experiences in the current business or previous employment. Changes handled poorly may cause resistance to future changes.

24 How much were the following a feature of the implementation?
Please choose the appropriate response for each item:

	Not at all	Small extent	Moderate extent	Great extent	Very great	I don't know

					extent	this.
Advanced Information Systems (MRP, ERP, other)						
5S System						
Just In Time Manufacture						
A3 Management, or Nemawashi or Catchball process						
Total Productive Maintenance						
Kaizen (Kaikaku) Improvement Events						
5 Why's						
Used and trained staff in simple problem solving.						
Defining Value						
Pull Systems						
Kanban						
Used statistical methods						
Mapping of the value stream						
Visual Systems						
Root Cause Analysis						
Engaging suppliers						
Engaging customers						

25 Rate the following.
Please choose the appropriate response for each item:

	Not at all	Small extent	Moderate extent	Great extent	Very great extent	I don't know this.
Did employees resist the change.						
Did a culture similar or conducive to the desired culture already exist.						
Were staff given clear goals or performance indicators.						
Did management continue to learn and participate throughout implementation.						
At the start of the implementation did management establish (or have) a sound knowledge of Lean.						

If other than Lean was implemented (e.g. Agile) answer above question for that methodology.

26 List other factors (if any) that you felt were important to the success and sustainability of the implementation.
(e.g. relationship building with customers and suppliers, departmental or other factors)

Please write your answer here:

27 What would you do differently?

Please write your answer here:

28 What were significant positive outcomes for the organisation?

Please write your answer here:

29 Were there significant negative outcomes? (List if any)

Please write your answer here:

30 Are you happy to be contacted regarding your answers to this survey? If so leave your email address here. Your answers will no longer be anonymous to the researchers but will not be shared with other parties.

Please write your answer here:

Answers will not be recorded until you click "Next" at the bottom of the page.

Lean Knowledge Survey

These are the final questions. We appreciate your time thus far. If you are able please do complete the survey. We need your support.

31 We had a previous survey entitled "Knowledge Survey (Productivity Systems)". Some of these questions are listed below. Have you previously completed them?

Please choose **only one** of the following:

- Yes
- No

32 Lean is an organisational change. Do you agree with the following statements?

"The extent that a manager understands Lean and Lean implementation is critical for the success of Lean. Understanding what is critical governs their decision-making, ensuring greater chances of success."

Please choose **only one** of the following:

- Strongly agree
- Somewhat agree
- Neutral
- Somewhat disagree
- Strongly disagree
- Don't know

33 In a small organisation (say less than 50 staff) the management's understanding of Lean should be the first and top priority to ensure an implementation is handled properly.

Please choose **only one** of the following:

- Strongly agree
- Somewhat agree
- Neutral
- Somewhat disagree
- Strongly disagree
- Don't know

34 To what extent are you familiar with the following?

Please choose the appropriate response for each item:

	Not at all	Small	Moderate	Great	Very	I don't

		extent	extent	extent	great extent	know this.
Lean or TPS	○	○	○	○	○	
Theory of Constraints	○	○	○	○	○	○
Agile Manufacturing	○	○	○	○	○	○
Agile for IT Development	○	○	○	○	○	○
Total Quality Management/ Quality Circles	○	○	○	○	○	○

35 Do the following statements represent your understanding of Lean?
(Answer "not at all" if the statement does not represent your <u>understanding</u> or "don't know" if you don't know about that concept)
Please choose the appropriate response for each item:

	Not at all	Small extent	Moderate extent	Great extent	Very great extent	I don't know this.
Lean is a simple repacking of JIT and quality systems, nothing new.	○	○	○	○	○	○
Lean implementation is of tools and processes for improving productivity.	○	○	○	○	○	○
Lean is tools or methods primarily for process or industrial engineers.	○	○	○	○	○	○
Lean means eliminating waste.	○	○	○	○	○	○
Lean gives workers training and empowerment to solve problems.	○	○	○	○	○	○
Lean means fragile (i.e. without buffers).	○	○	○	○	○	○
Lean is the implementation of new systems and ways of doing things to improve productivity.	○	○	○	○	○	○
Lean means respecting people.	○	○	○	○	○	○
Lean is the implementation of a company wide philosophy and strategy.	○	○	○	○	○	○
Lean implementation needs regularity and focus for sustained success.	○	○	○	○	○	○

	Not at all	Small extent	Moderate extent	Great extent	Very great extent	I don't know this.
Lean is a new label for industrial engineering and the work of industrial engineers.	○	○	○	○	○	○

36 What caused you to learn about Lean?

Please write your answer here:

37 You have completed the questions. Before you submit do you have any other comments?

Please write your answer here:

Thank you!

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Te Whare Wānanga o Waitaha
CHRISTCHURCH NEW ZEALAND

Thank you for your participation in this survey. Please pass on the following link to others who have implemented productivity systems.

A survey you may be interested in: http://bit.ly/LeanSurveyReferral

If you have any questions about the research and its finding you may send emails to: Mr. Antony Pearce - antony.pearce@pg.canterbury.ac.nz - or Dr. Dirk Pons - dirk.pos@canterbury.ac.nz -

Submit your survey.
Thank you for completing this survey.

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